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# CHANGES IN FRESH BEEF DURING COLD STORAGE ABOVE FREEZING.

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## HYGIENIC VALUE OF COLD STORAGE.

Cold storage is the most efficient method of preserving perishable foodstuffs in their natural condition, or in a state approaching that condition, for various periods of time. It is well known, however, that changes do take place in foodstuffs held in cold storage, and that, roughly speaking, the rate of deterioration or decay, although affected by many factors, is more rapid the higher the temperature. Moreover, the wholesomeness of cold-storage products depends not only upon proper conditions of storage, but also upon the condition of the products when placed in storage and upon the methods of handling subsequent to storage. The hygienic aspect of the cold-storage industry has had an increasing amount of attention during the last few years. There is an increasing need for exact and complete information concerning the changes which take place in foodstuffs held in cold storage, and in regard to the effect of various factors upon the quality and wholesomeness of such products. Much good work has been done but more remains to be accomplished.

## COMMERCIAL PRACTICES IN THE COLD STORAGE OF FRESH BEEF.

There are two general methods of handling fresh beef in cold storage, viz, (1) storage at temperatures above freezing, usually between 32° and 38° F., and (2) storage at temperatures below freezing, usually between 8° and 12° F. According to Holmes (1913), 3.1 per cent of the beef slaughtered commercially in this country in 1909 was placed in cold storage at temperatures below freezing, which would leave a remainder of 96.9 per cent that must have been stored at temperatures above freezing. Beef stored at temperatures above freezing is known as fresh or chilled beef. That stored at temperatures below freezing is known as frozen beef. This discussion is concerned only with chilled beef and the methods by which it is handled in the larger meat-packing establishments in this country.

The methods used in the commercial slaughter of cattle are so well standardized that they do not demand special discussion. When the carcass is completely dressed it is split down the back into two equal halves called "sides," which are hung on rails or trolleys. The sides are then washed clean, wiped dry, and run into coolers. In the larger establishments less than an hour is required from the time the animal is stunned until the carcass is placed in the cooler.

### REFRIGERATION.

"Coolers" are the names applied to the refrigerated rooms in which carcasses of beef or other meat food animals, or parts thereof, are stored at temperatures above freezing. Meat-packing establishments are usually supplied with two or more coolers for the handling of fresh beef. One of these is known as the "fore cooler," into which the warm beef is run immediately after slaughter, where it is usually held for from 12 to 18 hours until partially chilled. The other is known as the "main cooler," into which the partially chilled beef from the fore cooler is run and then held therein for shipment or other disposal.

The fore cooler is a very important factor in the proper handling of refrigerated beef. When warm beef is placed in a cooler at a temperature of about 32° F., the air soon becomes filled with the condensed-water vapors arising from the warm carcasses unless special provisions have been made for their disposal. If warm beef should be run into a cooler that contained chilled beef the water vapors would condense upon the cold beef and injure its appearance and keeping qualities. Likewise the warm beef causes a considerable rise in the temperature of the cooler, which may increase to 50° F., a temperature which would be injurious to chilled beef held in the same cooler. The temperature of the fore cooler is usually brought

down to about 32° F. before filling, though when filled with warm beef it may run up to 50° F.

The main cooler is simply a second cooler into which the partially chilled beef from the fore cooler is run to be thoroughly chilled and held for shipment. In some of the large meat-packing establishments, which have several beef coolers, warm beef is run into one cooler on one day, into another cooler on the second day, and so on, the chilled beef being removed from the first cooler in time for its refilling with warm beef. This practice accomplishes the same result as the use of a fore cooler.

## SYSTEMS OF REFRIGERATION.

In commercial meat-packing establishments in this country the ammonia-compression system of refrigeration is used almost entirely. There are, however, a number of methods by which the refrigeration is distributed for the purpose of chilling the coolers. The more important of these are: (1) Closed brine-coil system; (2) sheet-brine system; (3) brine-spray system. In each case the refrigerating agent is sodium chlorid or calcium chlorid brine that has been chilled by the direct expansion of liquid ammonia in closed coils.

*Closed-coil system.*—Refrigerated brine is pumped through closed coils located in bunkers directly above the coolers. The bunkers are so constructed as to provide for gravity circulation of air, the cold air falling from one side of the bunker into the cooler below and the warm air from the cooler rising at the other side to be refrigerated as it passes over the brine coils. This system also accomplishes a partial drying of the air as it passes over the cold brine coils, which condense a part of the moisture and the dissolved impurities that the air contains. The closed-coil system is the one most commonly used for the refrigeration of fresh-meat coolers.

*Sheet-brine system.*—This system is similar in principle to the closed-coil system. Instead of passing through closed coils, however, the refrigerated brine is allowed to trickle over a series of suspended muslin curtains located in a bunker room similar to that used in the closed-coil system.

*Brine-spray system.*—In this system the refrigerated brine is sprayed from a series of pipes located in a bunker room similar to that which is used in the two other systems. One advantage of this system over the other just mentioned is that less head room is required in the bunker room.

When properly installed any one of these systems is considered to give satisfactory results. It is very important, however, that a system of refrigeration for fresh-meat coolers should provide for abundant refrigeration and for a thorough and fairly rapid circulation of air.

## COMMERCIAL RIPENING OF MEATS.

The term "ripening," or "ageing," as applied to fresh beef, denotes the practice of holding such meat in cold storage at temperatures above freezing for various periods of time for the purpose of improving the quality of the meat, it being the opinion of experts that the ripening of beef greatly improves its quality, particularly as regards tenderness. This practice is not followed to any extent by the larger packing houses on their own account, but it is carried on to a certain extent by concerns which supply meats to high-class hotels and restaurants and to the dining-car service. As a rule, such concerns do not ripen meats in their own coolers, but select their cuts of meat and have them ripened in coolers belonging to the larger packing houses.

The practice of ripening meats is a simple one. Suitable cuts of meat, usually heavy, fancy ribs and loins and occasionally entire hind quarters, are hung in a cooler set aside for the purpose, or in a regular beef cooler, for from two to six weeks, depending upon the degree of ripeness desired. A dry cooler with good circulation of air is preferred, and the temperature is ordinarily held at 34° F. Depending upon the condition of the cooler as regards temperature and humidity, cuts of meat may show a slight growth of mold after from two to three weeks, and a heavy growth after from four to six weeks in storage. The growth of mold appears first and is heaviest on the cut surfaces of the meat. The degree of ripeness is judged largely by the length of the "whiskers," as the growth of mold is called in packing-house parlance. Such meats are wiped free of mold when sold; and the purchaser must assume any loss due to the necessity for trimming. As compared with the total amount of chilled beef handled in this country the quantity of specially ripened beef is quite small.

## PREVIOUS INVESTIGATIONS ON COLD STORAGE OF MEATS.

Only a brief discussion of the more important cold-storage investigations will be attempted.

Gautier (1897)[1] was one of the earliest workers to carry on extensive investigations concerning the changes which take place in meats during cold storage. He studied the chemical, physical, and organoleptic properties of fresh (French) beef and mutton as compared with frozen (Argentine) beef and mutton that had been held in cold storage between 5 and 6 months at —3° to —5° C. Artificial digestion experiments were also carried on. In general, the conclusions reached were to the effect that there was little difference in the composition of the fresh beef and mutton as compared with the

[1] References to literature will be found on page 100.

Wright (1912) made a chemical and bacteriological study of fresh and frozen New Zealand lamb and mutton. Carcasses of each class of animals were stored at 2° to 19° F. for periods ranging from 7 to 160 days. Samples were examined chemically and bacteriologically in the fresh condition and at intervals throughout the course of the experiment. The results of these experiments indicate the following changes in the lamb and mutton stored for 160 days at 2° to 19° F.: Loss of moisture amounting to from 2 to 3 per cent; an increase in proteose, peptone, and meat-base nitrogen; and no appreciable change in ammoniacal nitrogen or in the free acidity of the fat. The changes in chemical composition were ascribed to enzym action. The bacterial condition of the frozen meat remained the same as that of the fresh product. When freezing and subsequent thawing were carried on gradually, there was no alteration in the structure of the tissue. The nutritive value of the lamb and mutton was not affected by freezing and storage.

Ascoli and Silvestri (1913) carried on a series of experiments concerning the relative properties of fresh and frozen beef. Fresh, local beef (Italian), and frozen Australian and Argentine beef that had been held in cold storage about two months were used for the investigation. The following ground was covered in the studies with each class of meat: Chemical composition, digestibility in vitro, action on gastric secretion, digestibility with human subject, histological and autolytic changes. Certain changes were noted in the frozen as compared with the fresh meat, viz, a change in color, an increase in soluble protein which exuded in the form of a reddish fluid when the meat was thawed, the development of a peculiar taste, and a decrease in the aromatic odor of the broth. The changes were more apparent in the fat than in the muscular tissue. The changes noted were ascribed to the action of enzyms. The authors concluded that frozen meats may be regarded as a wholesome food product and may be eaten without injury.

## PURPOSE AND PLAN OF PRESENT INVESTIGATION.

*Purpose of investigation.*—This investigation was undertaken with the following objects in view: (1) To study the changes which take place in fresh beef stored at temperatures above freezing, with special reference to the effect of such changes upon the wholesomeness of the product; (2) to determine the causes of the changes which take place in fresh beef held in cold storage under the above conditions; (3) to determine the length of time that fresh beef can be held in cold storage at temperatures above freezing and remain in wholesome condition, with special reference to the effect of various factors upon the length of the storage period.

ter one hind quarter was cut from the carcass, wrapped in cheesecloth previously soaked in a solution of bichlorid of mercury (1–1,000) and then in dry cheesecloth and paper, and was at once transported to the laboratory by means of a motor truck, the trip requiring about half an hour.

*Preparation of samples.*—At the laboratory the hind quarter was transferred at once to a small bacteriological workroom, the floor, walls, and ceiling of which had been sprayed a short time previously with a disinfectant solution. Large plugs of meat, approximating 3 to 4 inch cubes, were cut from the muscular tissue, avoiding connective tissue and fat as much as possible. Sterile instruments were used in taking the samples and great care was exercised to make this procedure as nearly aseptic as possible. In taking the samples the outer portions of the hind quarter which had come in contact with the bichlorid gauze were of course rejected, these portions being trimmed away. The samples, which weighed from 274 to 512 grams, were immediately transferred to sterile crystallizing dishes fitted with glass covers. The dishes were then weighed and the covers sealed with adhesive tape and over the tape were placed strips of tin foil. This was done for the double purpose of preventing evaporation and bacterial contamination from the outside. The dishes containing the samples were then placed in the incubator.

*Bacteriological control of experiments.*—The samples were carefully inspected from day to day for evidences of bacterial growth. As the moist surfaces of the meat samples and the exuded juices furnished an excellent medium for the growth of contaminating microorganisms, such growths, when they occured, soon became perceptible to the naked eye. Out of a total of 36 samples, 24 showed visible bacterial growths upon incubation and these were rejected. In the case of these samples it was not necessary to make cultures, as the bacterial growths were quite apparent to the naked eye; in doubtful cases stained preparations were made. Nine of the samples showed no visible bacterial contamination after incubation periods ranging from 7 to 100 days, and these were subjected to careful bacteriological examinations in order to establish their sterility. In examining the samples bacteriologically, cultures were first made from the exuded juice and the outer portions of the meat samples. The samples were then cut in half with sterile instruments and cultures taken from the inner portions. Both anaerobic and aerobic cultures were made on several kinds of media. The 9 samples which showed no visible bacterial growths were found to be sterile upon bacteriological examination, and these samples were passed for chemical examination and study.

*Sampling of fresh material.*—The samples having been taken for incubation, a composite sample of the lean meat was taken for analy-

sis and placed in cold storage until the next day, when it was prepared for chemical examination. Analytical work was started practically 24 hours after slaughter, during which time the material used for analysis had been in cold storage 17 hours. All work in the preparation of the material for analysis, including the weighing of the material for individual determinations, was carried on in a refrigerated room at a temperature between 32° and 40° F. After the fresh material had been ground as finely as possible and transferred to glass jars which were then tightly stoppered, chemical work was started forthwith. In the case of the incubated samples, as soon as cultures had been taken for bacteriological examination, the dishes were again sealed and placed in a refrigerated room at a temperature of 24° F. for 2 or 3 days or until results had been obtained from the bacteriological examination of the samples. The meat was then prepared for analysis by the same methods used with the fresh material.

### PHYSICAL AND ORGANOLEPTIC CHANGES.

The sterile samples showed increasing losses in weight as the experiment progressed, ranging from 0.8 per cent in the sample incubated 7 days to 10.08 per cent in the sample incubated 100 days.

Certain observations on changes in the character of the samples during incubation may be of interest. The sample which had been incubated 7 days showed the following characteristics: There was no apparent disintegration of the tissues and the piece of meat had retained practically its original form; considerable juice had exuded which had turned light brown in color and which contained considerable sediment of a grayish-white color; after the dish had been opened and cultures for bacteriological examination had been taken, a strip of moist lead paper was inserted as a test for hydrogen sulphid, but no reaction was obtained; the exposed surface of the meat was light brown in color, while the surface which rested on the bottom of the dish was bright-pink in color. The cutting of a cross section showed that the meat was somewhat rubbery in texture and not noticeably tender. The cross section showed a brown zone extending inward for a distance of about one-fourth of an inch from the surface, except where the meat had rested upon the bottom of the dish, where the pink color extended to the surface. The interior of the sample was of a uniformly bright-pink color. The meat had a pleasant odor, somewhat similar to that of rare roast beef. The remainder of the sterile samples, which had been incubated for periods ranging from 14 to 100 days, showed characteristics so similar to those of the sample just described that a separate description of each sample does not seem to be necessary.

As the incubation period progressed there were some evidences of desiccation. There was no marked softening of the tissues, and there were no apparent evidences of muscular disintegration in any of the samples. The sample incubated 100 days was possibly somewhat more tender than the sample incubated 7 days. All samples showed the brown outer zone and pink interior. With increasing age there was some change in the odor of the samples, the one incubated 100 days having a rather old but not unpleasant odor. The juice that had exuded from the samples appeared to become more watery as the experiment progressed. In the case of some samples where the meat had rested against the side of the dish in such a way as to pocket some of the juice and protect it from the air the juice had a purplish-red color, similar to but more intense than that of the interior of the meat samples, in contrast to the brown color of the juice exposed to the air. The significance of this observation concerning the changes in color of the meat and juice has been discussed by one of the authors in another paper.[1]

A sample which had been incubated 103 days was broiled and sampled by three judges. The consensus of opinion as to the quality of the meat was about as follows: The meat is quite tender and has an old, highly acid, and rather disagreeable flavor which persists in the mouth after eating; the meat is not entirely objectionable but is not appetizing; no ill effects were suffered from eating the meat.

## CHEMICAL STUDIES.[2]

The analytical methods used were those which preliminary investigations had shown to be adapted to the work in hand. All determinations were made in duplicate, and except where noted were made upon the original material. Averages of closely agreeing duplicates are reported.

### METHODS OF ANALYSIS.

*Moisture.*—About 5 grams of the finely ground material were weighed from a weighing bottle into a previously weighed bottle cap and placed in a freezing compartment at a temperature of 25° F. At the end of 24 hours the bottle cap and its frozen contents were transferred to a well-chilled desiccator containing sulphuric acid, which was then evacuated to a pressure of from 3 to 5 millimeters. Two days afterwards the samples were removed and weighed, after which the drying in vacuo was continued over fresh concentrated sulphuric acid until a constant weight was obtained.

This method has the merit of guarding the sample against chemical changes during the course of the determination and of leaving the dried substance in a porous condition that greatly facilitates its complete extraction with ether.

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[1] Hoagland, Ralph, Formation of Hematoporphyrin in Ox Muscle During Autolysis. Journal of Agricultural Research, v. VII, p. 41–45, Oct. 2, 1916.

[2] The authors desire to extend their thanks to Mr. Robert H. Kerr for having made the analyses of the fats which are reported in this paper.

the nature and quantity of the soluble constituents of the muscles, either in fresh condition or after autolysis or cold storage.

The solvent used was 0.9 per cent aqueous solution of sodium chlorid that had been saturated with thymol by shaking with a concentrated chloroform solution of that substance. The preparation of the extract in these experiments was always begun as soon as possible after the grinding of the samples. The entire process was carried on in refrigerated rooms, the preparation of the extract at a temperature between 34° and 45° F., and subsequent extraction at a temperature between 34° and 36° F. The solvent was cooled to about 34° F. before use.

One hundred grams of the finely ground meat were weighed into a beaker and transferred quantitatively, with the aid of some of the solvent, to a 7-inch porcelain mortar. The meat was mascerated with the solvent to a smooth pulp, and quantitatively transferred to a 2,000 c. c. volumetric flask with the aid of a stream of the solvent from a wash bottle. The contents of the flask were then diluted to the mark with the isotonic solution, and the flask was placed in a cold-storage room at a temperature between 34° and 36° F. The suspension thus prepared was shaken at intervals of not less than an hour during the remainder of the day, and at like intervals during the morning of the following day, until at the expiration of the twenty-third hour it had been shaken on eight different occasions. After settling for another hour, it was filtered, the clear filtrate being used for the determination of the soluble constituents of the meat.

A determination of the volume displaced by the insoluble material has convinced us that the error caused by its presence is negligible.

*Total solids* were determined by evaporating 50 c. c. of the extract to dryness in a platinum dish on a steam bath, and by subsequently drying to constant weight at 100° C. Correction was made later for the sodium chlorid contained in the extract.

*Ash.*—The residue from the determination of total solids was carefully charred in an electric furnace, the temperature being kept below 600° C. in order to guard against volatilization of sodium chlorid. The charred mass was extracted with hot distilled water, filtered, washed, and the residue then ignited in the original dish. The filtrate was then transferred to the dish, evaporated to dryness, dried at 150° C. for several hours, and finally ignited for a short time at a temperature under 600° C. The dish was covered during ignition to avoid loss by decrepitation. Correction was made for the sodium chlorid content of the ash.

*Sodium chlorid.*—The ash was extracted with hot water, the filtrate made to volume, and sodium chlorid was determined in an aliquot portion by means of a standard solution of silver nitrate, with potassium chromate as an indicator.

*Organic extract* was obtained by substracting the percentage of ash from that of total solids.

*Total soluble nitrogen* was determined in 100 c. c. of the extract by the Kjeldahl-Gunning method.

*Coagulable nitrogen.*—One hundred cubic centimeters of extract was transferred to a 150 c. c. beaker, heated on a steam bath until the protein had coagulated, and then neutralized to litmus paper by the addition of a standard solution of sodium hydroxid. The solution was then heated on the steam bath until the original volume had been reduced by about one-third, after which it was filtered and the precipitate washed with hot water until free from sodium chlorid. Nitrogen was then determined in the precipitate.

shaking the apparatus for 2 minutes each at the beginning, in the middle, and at the end of the reaction period.

The results of this determination are reported in terms of percentages of elementary nitrogen.

*Acidity* was determined by titrating 100 c. c. of the extract against tenth-normal sodium hydroxid, using phenolphthalein as an indicator. Results are calculated in terms of lactic acid.

*Total soluble phosphorus*.—For this determination, 100 c. c. of the 0.9 per cent sodium chlorid extract was used. The method of determination was identical with the method used for the estimation of total phosphorus.

*Soluble inorganic phosphorus* was determined by the method of Chapin and Powick (1915), which consists essentially in the removal of the protein material by means of picric acid and the subsequent double precipitation of the inorganic phosphorus from an aliquot of the filtered picric acid solution, first, as magnesium ammonium phosphate and afterwards as ammonium phosphomolybdate according to the method of Lorenz (1901). "Modification B" of this method was used, no correction being made for the volume of the picric acid coagulum. For the sake of brevity the details of this method must be omitted. A complete description will be found in the original article by Lorenz.

The results are reported in terms of percentages of elementary phosphorus.

*Soluble organic phosphorus*.—The percentage of soluble organic phosphorus was obtained by subtracting the percentage of soluble inorganic phosphorus from that of total soluble phosphorus.

## COMPOSITION OF DIFFERENT MUSCLE BUNDLES FROM A HIND QUARTER OF A STEER.

The original plan for the conduct of the autolysis experiment was to determine the changes taking place in individual bundles of muscles; but in practice it was found in the course of some unreported work that it would be impracticable to obtain a sufficient number of sterile samples by this procedure. This plan was therefore abandoned and it was decided to take the samples for incubation at random from the muscular portions of the round of the hind quarter, and then to determine the composition of the fresh material by analyzing a composite sample taken from many parts of the round.

It was recognized that there might be slight differences in the composition of the different muscle bundles, a fact that would need to be taken into consideration in interpreting the results of an autolysis experiment conducted according to our plan. For this reason the composition of five of the more important bundles of muscles from the round of a fat steer was determined. The quarter of beef had been held in cold storage at 32°–34° F. for 48 hours previous to dissecting out the muscle bundles, and samples prepared for analysis were held in cold storage for an additional period of 24 hours, making a total of 72 hours' storage before analytical work was started.

Tables 1 to 5 inclusive show the composition of five muscle bundles from the hind quarter of the steer. Tables 1 and 3 show the com-

TABLE 4.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. Total soluble. | Nitrogen. Coagulable. | Nitrogen. Noncoagulable. | Nitrogen. Proteose. | Nitrogen. Amino. | Phosphorus. Total soluble. | Phosphorus. Soluble inorganic. | Phosphorus. Soluble organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hours. | | | | | | | | | | | | |
| 100 | Semimembranosus muscle.... | 48 | 32.73 | 5.08 | 27.65 | 3.77 | 4.38 | 2.36 | 2.02 | 0.125 | 0.3940 | 0.733 | 0.475 | 0.258 |
| 101 | Biceps femoris muscle.......... | 48 | 32.95 | 5.20 | 27.75 | 3.46 | 4.36 | 2.42 | 1.94 | .107 | .3977 | .714 | .440 | .274 |
| 102 | Vastus externus muscle........ | 48 | 29.83 | 4.65 | 25.18 | 3.49 | 3.96 | 2.07 | 1.89 | .109 | .3768 | .696 | .461 | .235 |
| 103 | Semitendinosus muscle......... | 48 | 32.06 | 4.82 | 27.24 | 3.54 | 4.49 | 2.48 | 2.01 | .085 | .3835 | .735 | .475 | .260 |
| 104 | Rectus femoris muscle......... | 48 | 29.62 | 4.48 | 25.14 | 2.99 | 3.85 | 1.99 | 1.86 | .070 | .3971 | .694 | .483 | .211 |

TABLE 5.—*Distribution of nitrogen and phosphorus, expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. | Nitrogen. Total. | Nitrogen. Soluble. | Nitrogen. Coagulable. | Nitrogen. Noncoagulable. | Nitrogen. Proteose. | Nitrogen. Amino. | Nitrogen. Ammoniacal. | Phosphorus. Total. | Phosphorus. Insoluble. | Phosphorus. Soluble. | Phosphorus. Soluble inorganic. | Phosphorus. Soluble organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hours. | | | | | | | | | | | | |
| 100 | Semimembranosus muscle. | 48 | 100.00 | 28.53 | 15.37 | 13.16 | 0.814 | 2.57 | 0.244 | 100.00 | 20.19 | 79.81 | 51.73 | 28.08 |
| 101 | Biceps femoris muscle...... | 48 | 100.00 | 29.52 | 16.38 | 13.14 | .724 | 2.69 | .266 | 100.00 | 22.67 | 77.33 | 47.65 | 29.68 |
| 102 | Vastus externus muscle... | 48 | 100.00 | 26.87 | 14.04 | 12.83 | .739 | 2.56 | .225 | 100.00 | 21.83 | 78.17 | 51.80 | 26.37 |
| 103 | Semitendinosus muscle.... | 48 | 100.00 | 29.62 | 16.36 | 13.26 | .561 | 2.53 | .276 | 100.00 | 20.28 | 79.72 | 51.53 | 28.19 |
| 104 | Rectus femoris muscle.... | 48 | 100.00 | 26.42 | 13.66 | 12.76 | .480 | 2.73 | .263 | 100.00 | 21.27 | 78.73 | 54.75 | 23.98 |

## CHEMICAL CHANGES TAKING PLACE DURING ASEPTIC AUTOLYSIS OF BEEF.

Tables 6 to 11, inclusive, show the chemical changes which took place in 9 samples of the muscular tissues from a hind quarter of a steer that were incubated at 37° C. for periods ranging from 7 to 100 days.

Table 6 shows the composition of the tissue expressed in terms of percentages of the original material. On account of variations in the moisture content of the samples, due to losses by evaporation during incubation, and because of appreciable variations in the fat content of the samples, the data do not show the true extent of the changes which took place in the composition of the material during autolysis, a better comprehension of which may be obtained from Table 7, which shows the composition of the samples expressed in terms of moisture-free and fat-free material.

*Moisture, fat-free basis* shows a fairly regular decrease as the period of incubation increases, the sample incubated 100 days containing 72.64 per cent, as compared with 76.61 per cent in the fresh material.

TABLE 7.—*Composition expressed in terms of percentage of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Incubation period. | Moisture, fat-free basis. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total. | Soluble. | Insoluble. |
| | | *Hours.* | *Days.* | | | | | | | |
| 109 | Composite sample, left hind quarter | 24 | 0 | 76.61 | 4.85 | 15.26 | 0.0382 | 0.899 | 0.718 | 0.181 |
| 110 | Sample No. 22 | 24 | 7 | 76.66 | 5.01 | 15.69 | .0815 | .938 | .836 | .102 |
| | Change | 0 | 7 | +0.05 | +0.16 | +0.43 | +.0433 | +.039 | +.118 | −.079 |
| 111 | Sample No. 17 | 24 | 14 | 76.46 | 4.96 | 15.55 | .0996 | .918 | .855 | .063 |
| | Change | 0 | 14 | −0.15 | +0.11 | +0.29 | +.0614 | +.019 | +.137 | −.118 |
| 112 | Sample No. 11 | 24 | 21 | 76.02 | 5.09 | 15.48 | .1084 | .947 | .877 | .070 |
| | Change | 0 | 21 | −0.59 | +0.24 | +0.22 | +.0702 | +.048 | +.159 | −.111 |
| 113 | Sample No. 12 | 24 | 28 | 75.33 | 4.58 | 14.54 | .1464 | .878 | .811 | .067 |
| | Change | 0 | 28 | −1.28 | −0.27 | −0.72 | +.1082 | −.021 | +.093 | −.114 |
| 120 | Sample No. 33 | 24 | 42 | 74.52 | 4.73 | 14.85 | .1478 | .885 | .835 | .050 |
| | Change | 0 | 42 | −2.09 | −0.12 | −0.41 | +.1096 | −.014 | +.117 | −.131 |
| 121 | Sample No. 18 | 24 | 64 | 75.28 | 4.94 | 14.33 | .2134 | .872 | .823 | .049 |
| | Change | 0 | 64 | −1.33 | +0.09 | −0.93 | +.1752 | −.027 | +.105 | −.132 |
| 122 | Sample No. 32 | 24 | 77 | 73.48 | 4.71 | 14.68 | .1868 | .884 | .850 | .034 |
| | Change | 0 | 77 | −3.12 | −0.14 | −0.58 | +.1486 | −.015 | +.132 | −.147 |
| 124 | Sample No. 3 | 24 | 93 | 73.49 | 4.93 | 14.30 | .2284 | .875 | .835 | .040 |
| | Change | 0 | 93 | −3.13 | +0.08 | −0.96 | +.1902 | −.024 | +.117 | −.141 |
| 125 | Sample No. 2 | 24 | 100 | 72.64 | 4.76 | 15.23 | .2362 | .882 | .867 | .015 |
| | Change | 0 | 100 | −3.97 | −0.09 | −0.03 | +.1980 | −.017 | +.149 | −.166 |

Table 8 shows the composition of the 0.9 per cent sodium chlorid extract of the meat expressed in terms of percentages of the original material; but the changes in the composition of the extract are shown more clearly in Table 9, where the results are calculated in terms of percentages of the moisture-free and fat-free material. Table 9 shows the composition of the 0.9 per cent sodium chlorid extract of the samples expressed in terms of moisture-free and fat-free material.

*Total solids.*—The data for total solids show some striking peculiarities. The samples incubated for 7, 14, and 21 days show decreases amounting to 4.54, 2.89, and 3.75 per cent, respectively, while the samples incubated for periods ranging from 28 to 100 days show fairly regular increases varying from 3.62 to 8.77 per cent. The probable reasons for these irregular changes in total solids will be discussed in connection with soluble nitrogen, Table 10.

*Ash of extract.*—There is a fairly marked increase in this constituent in the incubated samples as compared with the fresh material, but the extent of the increase bears no relation to the length of the incubation period. In the column headed "Total soluble phosphorus" increases may be noted in that constituent that go to confirm and explain the increases in ash of extract. The increase in ash of extract is apparently due, in large part at least, to the change of insoluble phosphorus compounds (probably organic) to soluble forms. The cause and nature of these changes will be discussed in connection with changes taking place in the phosphorus compounds.

*Organic extractives* were determined by subtracting the percentage of ash from that of total solids. The same general changes may be noted in this constituent as have previously been noted in case of total solids.

*Acidity.*—The samples incubated for 7, 14, and 21 days, respectively, show practically no changes in acidity; while the samples incubated for longer periods show quite marked increases, ranging from 1.18 per cent in case of the sample incubated 42 days to 1.87 per cent in case of the sample incubated 77 days. It is of interest to note that the marked increases in acidity that took place in the samples incubated for periods ranging from 28 to 100 days are accompanied by rather marked increases in organic extractives and total soluble nitrogen, which would indicate that the acid-forming and the proteolytic enzyms were most active at the same time. The presence of autolytic acid-forming enzyms in various body tissues is well known. (See Inouye, 1908, and Vernon, 1910.) Such enzyms produce both volatile and nonvolatile acids, among which are lactic, succinic, formic, acetic, and butyric. The action of lactic acid producing enzyms appears to have been studied most extensively.

*Total soluble nitrogen.*—This constituent exhibits changes similar to those previously noted in case of total solids and organic extractives. The sample incubated for 7 days shows a marked decrease in soluble nitrogen that amounts to 0.895 per cent; samples incubated for 14 and 21 days show gradually reduced decreases; while samples incubated for periods ranging from 28 to 100 days show gradual increases in this constituent. It is of interest to note that the decrease in soluble nitrogen in the case of the sample incubated 7 days, which amounts to 0.895 per cent, is nearly as great as the increase in soluble nitrogen in the case of the sample incubated 100 days, which amounts to 1.005 per cent. It is apparent that there was at first a rapid decrease in soluble nitrogen, as noted in case of the sample incubated 7 days, while subsequently the change was in the other direction, although in the case of the samples incubated 14 and 21 days the reversal in direction is apparent only when the results are compared with those from the sample incubated 7 days.

The probable causes of these changes will be discussed in connection with the nitrogen data in Table 10.

*Coagulable nitrogen.*—There is a marked decrease in the coagulable nitrogen of the samples as the period of incubation increases. The fresh material contains 2.715 per cent coagulable nitrogen, while the sample incubated 100 days contains only 0.536 per cent, so that the decrease amounts to 2.179 per cent. The causes of these changes will be discussed in connection with Table 10.

*Noncoagulable nitrogen.*—The data for noncoagulable nitrogen show a fairly regular increase in this constituent throughout the course of the experiment, but the rate of increase varies considerably

TABLE 8.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Incubation period. | Total solids. | Ash. | Organic extractives. | Acid, as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total soluble. | Coagulable. | Noncoagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *Hours.* | *Days.* | | | | | | | | | | | | |
| 109 | Composite sample, left hind quarter | 24 | 0 | 7.39 | 1.02 | 6.37 | 0.72 | 1.04 | 0.621 | 0.419 | 0.015 | 0.0782 | 0.164 | 0.115 | 0.049 |
| 110 | Sample No. 22 | 24 | 7 | 6.32 | 1.17 | 5.15 | .69 | .831 | .356 | .475 | .045 | .1412 | .190 | .182 | .008 |
| 111 | Sample No. 17 | 24 | 14 | 6.64 | 1.30 | 5.34 | .71 | .903 | .304 | .599 | .065 | .1931 | .193 | .180 | .013 |
| 112 | Sample No. 11 | 24 | 21 | 6.68 | 1.29 | 5.39 | .74 | .950 | .313 | .637 | .057 | .2161 | .205 | .192 | .013 |
| 113 | Sample No. 12 | 24 | 28 | 8.99 | 1.26 | 7.73 | 1.13 | 1.14 | .195 | .945 | .071 | .4232 | .193 | .177 | .016 |
| 120 | Sample No. 33 | 24 | 42 | 8.88 | 1.18 | 7.70 | 1.07 | 1.17 | .217 | .953 | .057 | .4641 | .207 | .191 | .016 |
| 121 | Sample No. 18 | 24 | 64 | 8.90 | 1.38 | 7.52 | 1.08 | 1.10 | .135 | .965 | .076 | .4715 | .196 | .184 | .012 |
| 122 | Sample No. 32 | 24 | 77 | 9.84 | 1.33 | 8.51 | 1.28 | 1.31 | .163 | 1.147 | .067 | .6100 | .217 | .203 | .014 |
| 124 | Sample No. 3 | 24 | 93 | 9.90 | 1.33 | 8.57 | 1.22 | 1.33 | .131 | 1.199 | .067 | .6208 | .215 | .205 | .010 |
| 125 | Sample No. 2 | 24 | 100 | 10.95 | 1.39 | 9.56 | 1.27 | 1.48 | .143 | 1.337 | .067 | .7658 | .231 | .217 | .014 |

with the samples incubated for different periods of time. The maximum increase in noncoagulable nitrogen, which occurred in the sample incubated for 100 days, amounts to 3.184 per cent, while the corresponding increases in total soluble nitrogen amount to only 1.005 per cent, so that the transformation of insoluble muscle protein into soluble forms was only about one-third as great as the change of soluble coagulable protein into noncoagulable forms.

*Proteose nitrogen.*—There is a comparatively small amount of proteose nitrogen present in any of the samples. The most rapid increase in this constituent took place in the sample incubated 7 days, while the sample incubated 64 days shows the greatest increase. The sample incubated 100 days contains less proteose nitrogen than that incubated 7 days.

*Amino nitrogen.*—The changes in amino nitrogen will be discussed in connection with Table 10, where they are shown more clearly.

*Phosphorus compounds.* — The changes in the soluble phosphorus compounds will be discussed in connection with Table 11, for reasons that have already been indicated.

Table 10 shows the distribution of nitrogen and phosphorus compounds in the various samples referred to 100 parts of each constituent in the fresh material.

*Total nitrogen.*—As has been previously noted, there are some slight and irregular changes in this constituent, which are apparently without significance.

*Soluble nitrogen.*—The data under this heading simply show more clearly changes that have been previously discussed in connection with Table 9. There are at first marked decreases in the soluble nitrogen in the samples incubated for 7, 14, and 21 days, after which there are gradual increases in this constituent as the incubation period progresses. The total increase in the sample incubated 100 days amounts to 22.12 per cent of the soluble nitrogen present in the fresh sample. This increase is practically the same as the decrease in soluble nitrogen in the sample incubated 7 days.

The increase in soluble nitrogen in the incubated samples is clearly due to the action of a proteolytic endoenzym, capable of attacking native proteins and of working in an acid medium. The presence of such an enzym in muscular tissues, as well as in other body tissues, is generally recognized. Vernon (1910) names such an enzym "protease." A discussion of the factors limiting the total extent of the action of this enzym upon the insoluble muscle proteins is hardly within the province of this paper.

The decrease in soluble nitrogen in case of the samples incubated for 7, 14, and 21 days is harder to explain. The following appears to be the most reasonable explanation of this condition. It is a well-known fact that muscular tissue contains a much higher proportion of soluble protein before rigor mortis has set in than after that process is complete. Oppenheimer (1909) cites experiments where 87.3 per cent of the total protein of muscular tissue was found in soluble condition before rigor mortis had set in, while only 28.5 was present in the soluble form after rigor was complete. In our experiments the fresh material was analyzed 24 hours after slaughter of the animal, at which time rigor mortis was assumed to be complete. The fact that the samples incubated for 7, 14, and 21 days show decreases in total soluble nitrogen as compared with the fresh material, indicates very clearly that rigor mortis was not complete when the fresh muscular tissue was analyzed. It may be noted that while the samples incubated for 7, 14, and 21 days show decreases in total soluble nitrogen, as compared with the fresh material, the maximum decrease was reached in case of the sample incubated 7 days, and from that time on the change was in the other direction. This fact indicates that the coagulation of muscle proteins, which accompanies rigor mortis, was complete at the end of 7 days and probably at an earlier date.

*Coagulable nitrogen.*—There is a marked decrease in this constituent during the course of the experiment, the decrease being most rapid during the first 7 days. The sample incubated for 100 days contains only 19.76 per cent of the amount of coagulable protein in the fresh sample. However, these figures do not show the full extent of the transformation of coagulable protein into noncoagulable

TABLE 10.—*Distribution of nitrogen and phosphorus on basis of 100 parts of respective constituents at beginning of incubation period.*

| Serial No. | Description of sample. | Storage period. | Incubation period. | Nitrogen. Total. | Nitrogen. Soluble. | Nitrogen. Coagulable. | Nitrogen. Noncoagulable. | Nitrogen. Proteose. | Nitrogen. Amino. | Nitrogen. Ammoniacal. | Phosphorus. Total. | Phosphorus. Insoluble. | Phosphorus. Soluble. | Phosphorus. Soluble inorganic. | Phosphorus. Soluble organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Hours.* | *Days.* | | | | | | | | | | | | |
| 109 | Composite sample, left hind quarter | 24 | 0 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 110 | Sample No. 22 | 24 | 7 | 102.81 | 80.31 | 57.62 | 113.94 | 301.53 | 181.40 | 213.41 | 104.26 | 56.12 | 116.40 | 159.30 | 15.88 |
| 111 | Sample No. 17 | 24 | 14 | 101.92 | 87.99 | 49.61 | 144.87 | 439.13 | 250.21 | 260.89 | 102.04 | 34.56 | 119.06 | 158.54 | 26.54 |
| 112 | Sample No. 11 | 24 | 21 | 101.45 | 89.34 | 49.30 | 148.70 | 371.65 | 262.63 | 283.99 | 105.29 | 38.48 | 122.14 | 163.57 | 25.05 |
| 113 | Sample No. 12 | 24 | 28 | 95.27 | 105.33 | 30.17 | 216.73 | 454.84 | 519.91 | 383.63 | 97.63 | 36.78 | 112.98 | 147.93 | 31.05 |
| 120 | Sample No. 33 | 24 | 42 | 97.33 | 104.12 | 32.34 | 210.52 | 351.71 | 549.07 | 387.22 | 98.41 | 27.45 | 116.32 | 153.72 | 28.68 |
| 121 | Sample No. 18 | 24 | 64 | 93.91 | 101.36 | 20.83 | 220.73 | 485.57 | 577.69 | 559.08 | 96.99 | 27.42 | 114.54 | 153.38 | 23.51 |
| 122 | Sample No. 32 | 24 | 77 | 96.22 | 113.10 | 23.57 | 245.79 | 401.06 | 700.15 | 489.31 | 98.25 | 18.52 | 118.38 | 158.50 | 24.35 |
| 124 | Sample No. 3 | 24 | 93 | 93.71 | 113.66 | 18.75 | 254.33 | 393.98 | 705.32 | 598.30 | 97.31 | 21.86 | 116.33 | 158.11 | 18.44 |
| 125 | Sample No. 2 | 24 | 100 | 99.83 | 122.12 | 19.76 | 273.82 | 383.29 | 840.09 | 618.73 | 98.10 | 8.55 | 120.69 | 162.12 | 23.60 |

though they seem to be more nearly in conformity with a regular rule. On the whole, the rate of ammonia production decreases as the ammonia accumulates; yet in view of the small amounts in which this constituent is present (see Table 9), it would seem that the ammonia is but an index of the retarding agent and not the retarding agent itself.

The production of ammonia is clearly due to enzym action, but the nature of the specific enzym and of the mother substance remains to be determined.

Table 11 shows the distribution of nitrogen and phosphorus expressed in terms of percentages of total nitrogen and total phosphorus.

*Soluble nitrogen* constitutes 29.8 per cent of the total nitrogen in the fresh material, 23.28 per cent in the material incubated for 7 days, and 36.45 per cent in the sample incubated for 100 days. The decrease in the ratio of soluble nitrogen to total nitrogen in the samples incubated for 7, 14, and 21 days confirms similar data presented in Table 10.

*Coagulable nitrogen* makes up 17.79 per cent of the total nitrogen in the fresh material and only 3.52 per cent in the sample incubated 100 days. More than 80 per cent of the coagulable nitrogen present in the fresh material has been converted into noncoagulable forms.

*Proteose nitrogen* constitutes a relatively small proportion of the total nitrogen both in the fresh and in the incubated material.

*Amino nitrogen.*—In the course of 100 days of autolysis the amino nitrogen has increased from 2.24 per cent to 18.86 per cent of the total nitrogen, or from less than one-tenth to more than one-half of the total soluble nitrogen.

*Insoluble phosphorus.*—The ratio of insoluble phosphorus to total phosphorus is seen to be a decreasing function of the time of incubation, and while the rate of decrease is not entirely regular it will be seen that, on the whole, the rate diminishes as the incubation period is extended. At the end of the one-hundredth day of incubation but 1.76 per cent of the total phosphorus remains in insoluble form, as against 20.16 per cent originally present. These changes may be considered as due to the action of the enzyms lipase and nuclease upon the phosphatids and nucleic acids, respectively.

*Total soluble phosphorus.*—The changes in the ratio of total soluble phosphorus to total phosphorus are naturally equal and opposite to corresponding changes in the ratio of insoluble phosphorus to total phosphorus, and have no further significance.

*Soluble organic phosphorus.*—The figures for the ratio of soluble organic phosphorus to total phosphorus are peculiar, in that during the first seven days of autolysis this ratio decreased from its initial value of 23.87 per cent to its minimum value of 3.64 per cent. This large initial decrease, however, should not be regarded with suspicion, since the continued increase in soluble inorganic phosphorus indicates the continued cleavage of organic phosphorus that one would expect. It would appear, therefore, that after the first energetic cleavage of the preformed soluble organic phosphorus compounds, the activity of the phosphatase decreases, and that new soluble organic compounds of phosphorus—cleavage products from the insoluble fraction—accumulate at a rate that is sometimes greater than the rate at which they are broken down by the phosphatase. The possibility, of course, is not excluded that the accumulating phosphorus compounds are inherently less susceptible to the action of the phosphatase than are those originally present in the fresh meat.

*Soluble inorganic phosphorus.*—Except in the case of samples Nos. 112 and 113, the ratio of soluble inorganic phosphorus to total phosphorus increases continuously throughout the experiment, until at the end of the one-hundredth day of autolysis it has attained a value of 92.50 per cent, as against its original value of 55.97 per cent—more than three-fourths of the increase having taken place during the first seven days of incubation.

### SUMMARY OF RESULTS OF AUTOLYSIS EXPERIMENTS.

The results of the autolysis experiments reported in this paper may be summarized as follows:

1. Physical changes in the samples of muscular tissue were not marked, even at the conclusion of the experiment, and consisted

(*a*) Insoluble phosphorus decreased rapidly early in the experiment and more slowly and fairly regularly during the remainder of the period, the total decrease amounting to 91.29 per cent of the amount present in the fresh material as calculated from the ratios of insoluble to total phosphorus.

(*b*) Total soluble phosphorus showed increases corresponding to the decreases in insoluble phosphorus, the total increase amounting to 23.05 per cent, as calculated from the ratios of total soluble phosphorus to total phosphorus.

(*c*) Soluble inorganic phosphorus increased rapidly early in the experiment, and more slowly toward the close, the total increase amounting to 65.27 per cent, as calculated from the distribution figures.

(*d*) Soluble organic phosphorus showed decreases corresponding to the increases in soluble inorganic phosphorus, the total decrease amounting to 75.95 per cent, as calculated from the organic phosphoric ratios.

8. There was no development of free hydrogen sulphid during the course of the experiment.

## COLD-STORAGE EXPERIMENTS WITH FRESH BEEF.

### PROCEDURE.

The work undertaken in this investigation naturally groups itself under two headings, viz, (1) Bacteriological and histological studies, and (2) chemical and physical studies. The bacteriological and histological investigations were conducted by Doctor McBryde, and the chemical and physical investigations by Mr. Hoagland and Mr. Powick. Organoleptic observations were carried on jointly.

The following general plans were observed in carrying on the work, and such additional details as seem pertinent will be mentioned in connection with the individual experiments.

High-grade fat steers were purchased as needed at a local stockyard and were slaughtered in the usual manner under the supervision of one of the writers in a local modern packing house, and were held there under refrigeration until chilled, usually for 48 hours. The two hind quarters were then cut from the carcass, carefully wrapped in cheesecloth and paper, and transported by motor truck to the cold-storage rooms of the Biochemic Division at the Bureau of Animal Industry. The trip usually required about one hour. The rooms referred to were as follows:

Room No. 1: 6 by 9 feet by 7 feet 6 inches high, with overhead bunker, closed brine-coil system of refrigeration, and automatic temperature control. Overhead rails were provided for hanging the meat. This room was used for storing the beef described in all of the following experiments except one, in which the beef was stored in the cooler of a local packing house.

Room No. 2: 6 by 6 feet by 7 feet 4 inches high, with overhead bunker, closed brine-coil system of refrigeration, forced circulation of air, and automatic temperature control. This room was used as a place in which to cut up the meat and prepare it for analysis, and for certain laboratory work which required a low temperature.

As soon as the beef was received from the packing house it was placed in cold-storage room No. 1, unwrapped, weighed, and hung up. During each storage experiment the temperature of the room was recorded continuously by means of a recording thermometer. It was the aim to keep the temperature at 32° to 36° F., but the exact temperature range will be stated in connection with each experiment. The humidity of the room was determined once each week by means of a sling hygrometer, and observations as to the condition of the meat were made at the same time. Each quarter of beef was weighed at the end of the period of storage.

## BACTERIOLOGICAL AND HISTOLOGICAL STUDIES.

In the bacteriological study of the carcasses the two main questions investigated were: (1) Whether bacteria are present in the muscular tissues of beef animals which have been passed as normal after careful ante-mortem and post-mortem examination, and (2) whether the bacteria and molds which grow on the surfaces of cold-stored meats penetrate the meats to any marked degree during varying periods of storage.

With regard to the second question, there are two methods by which the surface bacteria might penetrate the meats, namely, (1) by direct growth or extension into the muscular tissues or (2) by growth along the tendinous sheaths or connective-tissue elements between the muscle groups. In the present study the latter method was not investigated and the cultures were always made from the muscular tissue, avoiding the connective-tissue elements, the idea being to determine whether the bacteria actually penetrate the muscular tissue.

In examining the quarters bacteriologically the following procedure was adopted: A slice or section from 3 to 4 inches thick was cut from the upper portion of the round. From this slice a rectangular block extending from the outer surface to the bone was cut, as indicated by the dotted line in the diagram (fig. 1). This block, which measured about 4½ by 8 inches and weighed from 6 to 8 pounds, was first immersed in actively boiling water for three minutes, next in bichlorid solution (0.5 per cent) for five minutes, and was then wrapped in sterile gauze which had been wrung out in the bichlorid solution. This was done in order to sterilize the surface of the meat and to prevent the growth and possible penetration of bacteria from the outside, pending the taking of cultures.

It was not always possible to make cultures immediately, but they were always made within two hours; and during this time the block of meat was kept wrapped in the bichlorid gauze and at cold-storage temperature (34°–36° F.).

The short immersion in the boiling water served to coagulate the muscle protein to the depth of from 3 to 5 mm., but did not cause sufficient elevation of the inside temperature to have any injurious effect on the bacteria present. A test was made by introducing a thermometer into a block of meat of the size described above so that the bulb rested at the center of the meat mass, and there was no appreciable rise in temperature during the three minutes' interval in the hot water. The outer zone of coagulated protein served to prevent the penetration of the bichlorid solution into the meat.

Beginning about 1 inch from the outer surface a series of cultures were taken at intervals of an inch, proceeding from the outside toward the bone, and these cultures were numbered as indicated in the diagram. In taking the cultures a series of sterile scalpels were used, one being used to cut through the outer or surface portion, and others to make deeper cuts in order not to carry in any of the bichlorid solution adhering to the surface of the meat. Plugs of meat about a centimeter square were used in making the cultures. Cultures were made in neutral beef broth and in glucose agar from which the air had been expelled by boiling. When clouding occurred in the bouillon cultures, agar plates were poured and the organisms present were plated out.

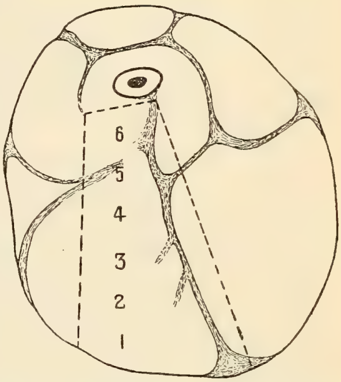


FIG. 1.—Diagram of a cross section of a beef round, showing points at which cultures were taken.

In 4 of the 7 carcasses studied, a small micrococcus was found. This organism was not generally distributed throughout the muscular tissue of any one quarter, but was encountered here and there. The fact that is was usually found at some distance below the outer surface, together with the fact that it was found in the fresh or chilled quarters as well as in the stored quarters, would indicate that it was present in the carcass at the time of slaughter. In three of the cold-stored carcasses, those held for 28, 54, and 63 days, it was encountered here and there and was not generally distributed through the muscular tissues, which would indicate that there had been no multiplication of the organism during the storage of these quarters. In the quarter which was held in storage for the longest period of time (i. e., 177 days) the micrococcus was found to be more generally distributed

*Rump.*—The entire rump was trimmed free of bone and connective tissue and as free as possible of fat, and the lean meat was then prepared for analysis as above.

*Loin.*—The loin was first cut into what are known as the short loin and the sirloin butt. From the first part porterhouse and club steaks are cut, while sirloin steaks are cut from the second part. Two sections, each about 2.5 to 3 inches thick, were then cut for analysis. The first section was cut from the small end of the sirloin butt, the second from the small end of the short loin. In the case of the quarters of beef that had been held in storage, the small end of the short loin was trimmed free of meat that had become dried or darkened through exposure before the section was cut for analysis.

For the purpose of testing the quality of the meat, a porterhouse steak about 2 inches thick was cut from the large end of the short loin.

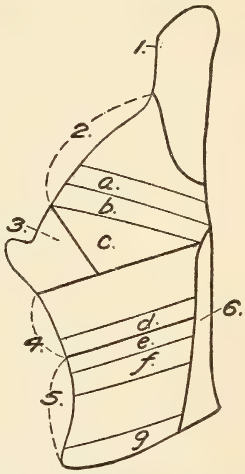


FIG. 2.—Diagram of a hind quarter of beef showing (by numbers) the usual wholesale cuts and (by letters) the sections taken for bacteriological and chemical examination.

*Cuts.*—(1) Shank; (2) round; (3) rump; (4, 5) loin; (4) sirloin butt; (5) short loin; (6) flank.

*Sections.*—(*a*, *c*) Sections for chemical examination; (*b*) section for bacteriological examination; (3) rump taken for chemical examination; (*d*, *g*) sections taken from loin for chemical examination; (*e*) test steak; (*f*) section for bacteriological examination.

*Flank.*—This cut was analyzed in only one experiment, because of the fact that the flank becomes so dry on long storage that it is difficult to prepare for analysis, and because it was considered that the analytical results would not be of great value.

*Fat samples.*—The following samples of fatty tissue were taken for analysis: External fat, intermuscular fat, and kidney fat.

All external fat was trimmed from each section of meat cut from the round, rump, and loin, and a sample of the combined material was taken for examination. The same practice was followed in case of the intermuscular fat. The entire kidney fat was stripped from the loin, cut up into small pieces, and reduced to a convenient quantity by quartering. This reduced quantity was ground and a sample of the ground fat was taken for examination. The sample of fatty tissue of each class was rendered in a large casserole on a steam bath and the fat was filtered and retained in bottles for analysis.

## METHODS OF ANALYSIS.

Analytical work on the samples of meat was usually started approximately 15 hours after the meat had been prepared for analysis.

The packing-house coolers in which the above carcass and those used in subsequent experiments were handled may be regarded as representative of beef coolers in modern packing houses. The overhead bunker, closed brine-coil system of refrigeration was used. The coolers were supplied with abundant refrigeration and the circulation of air was very good. On arrival at the bureau laboratories the quarters of beef were at once placed in cold-storage room No. 1, which has been previously described, and were unwrapped, weighed, and hung up. On the next morning, or 43 hours after the carcass first had been placed in cold storage, the right hind quarter was taken out and prepared for analysis by methods previously described, while the left hind quarter was held in cold storage for an additional period of two weeks.

*Storage.*—The temperature of cold-storage room No. 1 during the two weeks' storage period of the left hind quarter of carcass No. 1 ranged from 32° to 34° F. The humidity ranged from 72 to 84 per cent of saturation. This quarter showed a shrinkage in weight of 2.15 per cent.

QUALITY OF MEAT.

*Fresh quarter in storage 43 hours.*—This quarter of beef would have been classed as "choice." It was well covered with fat and had a heavy deposit of kidney fat. As it was being cut up the meat appeared well marbled with fat. The lean meat was dark red in color. The judges' opinions regarding the quality of the broiled test steak cut from this quarter of beef are as follows:

Mr. A.—The tenderloin portion is quite tender, has a good flavor, and is very palatable. The loin portion is rather tough, but has a good flavor. The flank end is very tough—almost too tough to eat.

Mr. B.—The tenderloin portion is quite tender, but not as tender as that from a high-class steak. The flank portion is very tough. On the whole the meat is juicy and of good flavor, but is rather tough.

Mr. C.—The tenderloin portion is very tender, has a good flavor, and is very palatable. The loin portion is rather tough and the flavor is not as high as might be expected in this class of meat. The flank portion is rather tough.

*Stored quarter in storage 15 days, 19 hours.*—At the end of the storage period the quarter of beef was in very good condition. The surface of the quarter was dry and firm, and the thin outer covering of connective tissue was parchmentlike in texture. The exposed, cut, muscular surface of the round and loin were dark brown in color and firm in texture. A slight growth of mold was visible about the shank.

As the quarter was being cut up for examination the meat appeared to be in good condition, and as far as could be judged by handling it appeared to be more tender than the meat from the corresponding quarter at the beginning of the storage period. The

TABLE 13.—*Composition expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Moisture, fat-free basis. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total. | Soluble. | Insoluble. |
| | | *D. H.* | | | | | | | |
| 1 | Round: Right hind quarter. | 1 19 | 75.83 | 4.55 | 14.46 | 0.0328 | 0.853 | 0.650 | 0.203 |
| 7 | Round: Left hind quarter... | 15 19 | 76.57 | 4.82 | 14.83 | .0365 | .888 | 681 | .207 |
| | Change................. | 14 | + 0.74 | + .27 | + .37 | + .0037 | + .035 | + .035 | + .004 |
| 2 | Rump: Right hind quarter.. | 1 19 | 76.38 | 4.59 | 14.51 | .0345 | .811 | .655 | .125 |
| 8 | Rump: Left hind quarter... | 15 19 | 76.96 | 4.74 | 14.75 | .0360 | .873 | .646 | .276 |
| | Change................. | 14 | + 0.58 | + .15 | + .24 | + .0015 | + .062 | − .009 | + .071 |
| 3 | Loin: Right hind quarter... | 1 19 | 76.58 | 4.50 | 14.62 | .0341 | .837 | .652 | .185 |
| 9 | Loin: Left hind quarter..... | 15 19 | 76.92 | 4.80 | 15.06 | .0323 | .858 | .653 | .205 |
| | Change................. | 14 | + 0.34 | + .30 | + .44 | − .0018 | + .021 | + .001 | + .020 |

Table 14 shows the composition of the 0.9 per cent sodium chlorid extract of the meat expressed in terms of percentages of the fresh material. On account of the effect upon the results of variations in the fat and moisture content of the meats from which these extracts were prepared, these data have been recalculated to the moisture-free and fat-free basis and are so expressed in Table 15.

Table 15 shows the composition of the 0.9 per cent sodium chlorid extracts of the meat expressed in terms of percentages of moisture-free and fat-free material.

Appreciable decreases took place in total soluble solids, ranging from 0.05 per cent in the case of the loin to 0.73 per cent in the case of the round. It will be recalled that in the autolysis experiment reported in this paper there was a distinct decrease in total solids in the early stages of the experiment.

The ash shows appreciable increases that go hand in hand with a much smaller average increase in total soluble phosphorus. Slight changes in ash of extract are not of great significance on account of the unavoidable error in correcting for the presence of relatively large amounts of sodium chlorid in the presence of small amounts of ash.

Organic extractives and acidity show appreciable decreases that are in harmony with similar changes noted in the early stages of the autolysis experiment previously reported.

Changes in nitrogen and phosphorous compounds will be discussed in connection with Tables 17 and 18.

Table 16 shows the composition of the fat at the beginning and end of the storage period.

The iodin numbers and refractive indices show practically no changes. There are appreciable increases in the acidity of the fats, ranging from 0.52 per cent in case of external fat to 0.17 per cent in case of the intermuscular fat. The increase in acidity of the in-

TABLE 14.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 1 | Round: Right hind quarter | 1 19 | 7.01 | 0.99 | 6.02 | 0.77 | 0.980 | 0.528 | 0.452 | 0.030 | ........ | 0.151 | 0.093 | 0.058 |
| 7 | Round: Left hind quarter | 15 19 | 6.67 | .99 | 5.68 | .70 | .922 | .456 | .466 | .037 | ........ | .155 | .112 | .043 |
| 2 | Rump: Round hind quarter | 1 19 | 6.78 | .92 | 5.86 | 8.74 | .946 | .518 | .428 | .034 | ........ | .147 | .090 | .057 |
| 8 | Rump: Left hind quarter | 15 19 | 6.52 | .98 | 5.54 | .68 | .874 | .471 | .403 | .033 | ........ | .142 | .110 | .032 |
| 3 | Loin: Right hind quarter | 1 19 | 6.81 | .94 | 5.87 | .71 | .973 | .538 | .435 | .026 | ........ | .146 | .091 | .055 |
| 9 | Loin: Left hind quarter | 15 19 | 6.39 | .95 | 5.64 | .66 | .930 | .503 | .427 | .045 | ........ | .141 | .107 | .034 |

TABLE 15.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 1 | Round: Right hind quarter | 1 19 | 30.09 | 4.25 | 25.84 | 3.29 | 4.20 | 2.27 | 1.93 | 0.130 | ........ | 0.650 | 0.398 | 0.252 |
| 7 | Round: Left hind quarter | 15 19 | 29.36 | 4.36 | 25.00 | 3.08 | 4.06 | 2.01 | 2.05 | .163 | ........ | .681 | .492 | .189 |
| | Change | 14 | −0.73 | +0.11 | −0.84 | −0.21 | −0.14 | −0.26 | +0.12 | +.033 | ........ | +.031 | +.094 | −.063 |
| 2 | Rump: Right hind quarter | 1 19 | 30.15 | 4.07 | 26.08 | 3.29 | 4.21 | 2.31 | 1.90 | .150 | ........ | .655 | .402 | .253 |
| 8 | Rump: Left hind quarter | 15 19 | 29.70 | 4.47 | 25.23 | 3.08 | 3.99 | 2.15 | 1.84 | .151 | ........ | .646 | .501 | .145 |
| | Change | 14 | −0.45 | +0.40 | −0.85 | −0.21 | −0.22 | −0.16 | −0.06 | +.001 | ........ | −.009 | +.099 | −.108 |
| 3 | Loin: Right hind quarter | 1 19 | 30.50 | 4.19 | 26.31 | 3.18 | 4.36 | 2.41 | 1.95 | .117 | ........ | .652 | .409 | .243 |
| 9 | Loin: Left hind quarter | 15 19 | 30.45 | 4.37 | 26.08 | 3.05 | 4.30 | 2.33 | 1.97 | .206 | ........ | .653 | .495 | .158 |
| | Change | 14 | −0.05 | +0.18 | −0.23 | −0.13 | −0.06 | −0.08 | +0.02 | +.089 | ........ | +.001 | +.086 | −.085 |

termuscular fat may be regarded as due to the action of the enzym lipase, while the greater increases in acidity noted in case of the external and kidney fats must be regarded as due to the combined action of the enzym lipase and of bacteria.

The fats appeared to be normal in character and gave no reaction for rancidity.

TABLE 16.—*Composition of fat.*

| Serial No. | Description of sample. | Storage period. | | Iodin number. | Refractive index 40°C. | Per cent acidity as oleic acid. | Rancidity. | Physical characters. |
|---|---|---|---|---|---|---|---|---|
| | | *D.* | *H.* | | | | | |
| 4 | Kidney fat: Right hind quarter.. | 1 | 19 | 42.43 | 1.4562 | 0.28 | Neg..... | Normal. |
| 10 | Kidney fat: Left hind quarter.... | 15 | 19 | 42.38 | 1.4562 | .68 | ...do..... | Do. |
| 5 | Intermuscular fat: Right hind quarter. | 1 | 19 | 46.86 | 1.4570 | .22 | ...do..... | Do. |
| 11 | Intermuscular fat: Left hind quarter. | 15 | 19 | 46.79 | 1.4570 | .39 | ...do..... | Do. |
| 6 | External fat: Right hind quarter. | 1 | 19 | 56.18 | 1.4580 | .33 | ...do..... | Do. |
| 12 | External fat: Left hind quarter... | 15 | 19 | 55.92 | 1.4580 | .85 | ...do..... | Do. |

Table 17 shows the distribution of nitrogen and phosphorus in the meat on the basis of 100 parts of the respective constituents in the material at the beginning of the storage period.

Slight apparent increases in total nitrogen are without significance, as has been noted previously.

Soluble nitrogen shows appreciable decreases which range from 5.23 per cent in the case of the rump to 1.38 per cent in the case of the loin. These decreases are in harmony with decreases in total solids and organic extractives, and with the decreases in soluble nitrogen previously noted in the early stages of the autolysis experiment, and they may be explained upon the same basis as the latter.

Coagulable nitrogen shows fairly marked decreases which range from 11.45 per cent in the case of the round to 3.32 per cent in the case of the loin. In part, these decreases are due to decreases in total nitrogen; but by referring to Table 15 it may be noted that the actual decreases in coagulable nitrogen are slightly larger, on the whole, than the decreases in total soluble nitrogen. These facts indicate a slight change of coagulable nitrogen into noncoagulable forms.

Noncoagulable nitrogen shows slight increases on the whole.

Proteose nitrogen shows relatively marked increases. However, it may be noted by referring to Table 15 that the actual amount of this constituent present is comparatively small.

Ammoniacal nitrogen appears to have increased in the round and in the rump, but to have decreased in the loin. As the total increase is somewhat greater than the decrease, the general tendency would seem to be toward an increase in this constituent.

TABLE 17.—*Distribution of nitrogen and phosphorus on basis of 100 parts of the respective constituents at beginning of storage period.*

| Serial No. | Description of sample. | Storage period. | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 1 | Round: Right hind quarter | 1 19 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 7 | Round: Left hind quarter | 15 19 | 102.56 | 96.67 | 88.55 | 106.22 | 125.38 | ......... | 111.28 | 104.10 | 102.17 | 104.71 | 123.56 | 74.91 |
| 2 | Rump: Right hind quarter | 1 19 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 8 | Rump: Left hind quarter | 15 19 | 101.65 | 94.77 | 93.07 | 96.84 | 100.67 | ......... | 104.35 | 107.69 | 145.36 | 98.70 | 124.56 | 57.59 |
| 3 | Loin: Right hind quarter | 1 19 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 9 | Loin: Left hind quarter | 15 19 | 103.01 | 98.62 | 96.68 | 101.03 | 176.07 | ......... | 94.72 | 102.55 | 111.17 | 100.11 | 121.04 | 64.83 |

TABLE 18.—*Distribution of nitrogen and phosphorus, expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 1 | Round: Right hind quarter | 1 19 | 100.00 | 29.05 | 15.70 | 13.35 | 0.90 | ......... | 0.23 | 100.00 | 23.78 | 76.22 | 46.69 | 29.53 |
| 7 | Round: Left hind quarter | 15 19 | 100.00 | 27.38 | 13.55 | 13.83 | 1.10 | ......... | .25 | 100.00 | 23.33 | 76.67 | 55.41 | 21.26 |
| | Change | 14 00 | 0.00 | −5.74 | −13.70 | +3.57 | +22.22 | ......... | +8.55 | 0.00 | − 1.89 | +0.59 | +18.68 | −28.01 |
| 2 | Rump: Right hind quarter | 1 19 | 100.00 | 29.01 | 15.92 | 13.09 | 1.03 | ......... | .24 | 100.00 | 19.26 | 80.74 | 49.56 | 31.18 |
| 8 | Rump: Left hind quarter | 15 19 | 100.00 | 27.05 | 14.58 | 12.47 | 1.02 | ......... | .24 | 100.00 | 25.98 | 74.02 | 57.33 | 16.69 |
| | Change | 14 00 | 0.00 | −6.76 | − 8.42 | −4.73 | − 0.97 | ......... | +2.75 | 0.00 | +34.89 | −8.32 | +15.68 | −46.47 |
| 3 | Loin: Right hind quarter | 1 19 | 100.00 | 29.82 | 16.48 | 13.34 | .80 | ......... | .23 | 100.00 | 22.05 | 77.95 | 48.92 | 29.03 |
| 9 | Loin: Left hind quarter | 15 19 | 100.00 | 28.55 | 15.47 | 13.08 | 1.37 | ......... | .21 | 100.00 | 23.90 | 76.10 | 57.75 | 18.35 |
| | Change | 14 00 | 0.00 | −4.26 | − 6.13 | −1.93 | +70.93 | ......... | −8.07 | 0.00 | + 8.39 | −2.37 | +18.05 | −36.79 |

Total phosphorus shows slight increases, the significance of which is not yet apparent.

It appears that a better comprehension of the changes in the various forms of phosphorus can be had from a consideration of Table 18.

Table 18 shows the distribution of nitrogen and phosphorous compounds expressed in terms of percentages of total nitrogen and total phosphorus. It may be noted that the percentage changes expressed in this table are not identical with those shown in Table 17. These differences are due to slightly different bases of calculation, as is indicated in the headings of the respective tables.

The nitrogen data, for the most part, are self-explanatory.

Insoluble phosphorus shows a large increase in the case of the rump and an appreciable increase in the case of the loin. The irregular nature of the changes in this constituent are of undetermined significance.

Total soluble phosphorus, of course, shows changes which are equal and opposite to the changes in insoluble phosphorus. The significance of these changes has not been established.

Soluble inorganic phosphorus shows appreciable increases which range from 15.68 per cent in the case of the rump to 18.68 per cent in the case of the round. These changes are in conformity with similar changes observed in the autolysis experiment, and may be regarded as due to the action of phosphatases upon organic phosphorous compounds.

Soluble organic phosphorus shows changes that are opposite in character to those observed in case of the inorganic phosphorus. There were marked relative decreases in organic phosphorus ranging from 28.01 per cent in the case of the round to 46.47 per cent in the case of the rump. Changes in organic phosphorus do not, as a rule, constitute as true an index of the extent of organic phosphorous cleavage as do the corresponding changes in inorganic phosphorus.

### EXPERIMENT NO. 2.

#### HISTORY OF CARCASS.

A "grade" Shorthorn steer of fair quality and finish was slaughtered in the usual manner. The carcass was allowed to hang for 2 hours on the killing floor, after which it was transferred to the fore cooler, where it was held for 17 hours, and then to the main cooler, where it was held for 29 hours. The temperature of the fore cooler ranged from 31° to 43° F. and that of the main cooler from 25° to 30° F. The humidity of the fore cooler was 95 per cent of saturation and that of the main cooler ranged from 75 to 95 per cent. After having been 46 hours in storage in the packing-house coolers, the two hind quarters of the carcass were carefully wrapped

The cut surface at the butt of the round had the normal odor and color. Where the muscular tissue had not been covered with fat and had been exposed to the air there was a hard dark-brown layer about one-eighth of an inch deep, due to desiccation, but no odor of putrefaction. The loin was in first-class condition, although the tip end, where the muscles had been exposed and had become dried out, required a little trimming. The kidney fat showed a slight growth of mold and had a rather strong odor. On the whole, this quarter of beef was considered to be in good marketable condition. The greatest apparent effect of storage upon the meat was that of desiccation.

When the meat was being prepared for analysis it was noted that the bundles of muscles separated with much greater ease than in the case of the fresh quarter of beef, and that apparently a marked softening of the intervening connective tissue had occurred.

The opinions of the respective judges concerning the quality of the broiled test steak are given below:

Mr. A.—The tenderloin portion is of good quality, has a good flavor, and is more tender than the steak from the fresh quarter. The meat is rather dry. The loin portion is much more tender than that of the fresh quarter, and is now quite palatable. While not first class, the meat is fairly tender and has a good flavor. The flank portion is decidedly more tender than in case of the fresh quarter and is now fairly palatable. The meat is rather dry, the flavor is fair, and the muscle fibers are coarse and tough.

Mr. B.—The steak is greatly improved in quality as compared with the steak from the fresh quarter of beef. While the meat is not of the highest quality, yet it has so improved in tenderness that even the flank portion can be eaten with ease.

Mr. C.—This steak is much better in quality in every respect than the steak from the fresh quarter of beef. The tenderloin is very tender, the loin portion is not quite as tender, and the flank end is fairly tender. The flavor of the steak is good.

### CHEMICAL EXAMINATION OF CARCASS NO. 2.

Tables 19 to 25, inclusive, show the changes that occurred in the composition of carcass No. 2 during 28 days in cold storage.

Table 19 shows the composition of the carcass expressed in terms of percentages of fresh material. For reasons previously given these data will not be discussed.

Table 20 shows the composition of the carcass expressed in terms of percentages of the moisture-free and fat-free material. There are slight losses of moisture due to evaporation during storage, and insignificant changes in ash. Changes in nitrogen and phosphorous compounds will be discussed in connection with Tables 24 and 25.

Table 21 shows the composition of the 0.9 per cent sodium chlorid extract expressed in terms of percentages of the fresh material. These data will be discussed as recalculated in Table 22.

TABLE 21.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 13 | Round: Right hind quarter | 2 17 | 6.75 | 1.09 | 5.66 | 0.75 | 0.967 | 0.556 | 0.411 | 0.024 | 0.086 | 0.154 | 0.128 | 0.026 |
| 25 | Round: Left hind quarter | 30 17 | 6.80 | 1.01 | 5.79 | .81 | .968 | .475 | .493 | .058 | .110 | .158 | .142 | .016 |
| 14 | Rump: Right hind quarter | 2 17 | 6.75 | 0.98 | 5.77 | .75 | .936 | .519 | .417 | .029 | .085 | .147 | .111 | .036 |
| 26 | Rump: Left hind quarter | 30 17 | 6.64 | 0.90 | 5.74 | .72 | .925 | .452 | .473 | .057 | .110 | .143 | .125 | .018 |
| 15 | Loin: Right hind quarter | 2 17 | 6.85 | 0.97 | 5.88 | .73 | .949 | .547 | .402 | .018 | .094 | .145 | .106 | .039 |
| 27 | Loin: Left hind quarter | 30 17 | 6.87 | 0.87 | 6.00 | .70 | .982 | .525 | .457 | .052 | .095 | .146 | .128 | .018 |

TABLE 22.—*Composition of 0.9 per cent sodium chlorid extract of meat, expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D. H.* | | | | | | | | | | | | |
| 13 | Round: Right hind quarter | 2 17 | 30.02 | 4.83 | 25.19 | 3.34 | 4.30 | 2.48 | 1.82 | 0.105 | 0.3813 | 0.687 | 0.570 | 0.117 |
| 25 | Round: Left hind quarter | 30 17 | 29.47 | 4.38 | 25.09 | 3.51 | 4.20 | 2.06 | 2.14 | .252 | .4752 | .687 | .615 | .072 |
| | Change | 28 | −0.55 | −0.45 | −0.10 | +0.17 | −0.10 | −0.42 | +0.32 | +0.147 | +.0939 | .000 | +.045 | −.045 |
| 14 | Rump: Right hind quarter | 2 17 | 30.67 | 4.43 | 26.24 | 3.41 | 4.25 | 2.36 | 1.89 | .130 | .3875 | .668 | .502 | .166 |
| 26 | Rump: Left hind quarter | 30 17 | 29.75 | 4.04 | 25.71 | 3.21 | 4.15 | 2.03 | 2.12 | .256 | .4910 | .642 | .561 | .081 |
| | Change | 28 | −0.92 | −0.39 | −0.53 | −0.20 | −0.10 | −0.33 | +0.23 | +0.126 | +.1035 | −.026 | +.059 | −.085 |
| 15 | Loin: Right hind quarter | 2 17 | 31.48 | 4.46 | 27.02 | 3.35 | 4.36 | 2.51 | 1.85 | .083 | .4320 | .668 | .489 | .179 |
| 27 | Loin: Left hind quarter | 30 17 | 30.69 | 3.89 | 26.80 | 3.13 | 4.39 | 2.34 | 2.05 | .232 | .4250 | .651 | .574 | .077 |
| | Change | 28 | −0.79 | −0.57 | −0.22 | −0.22 | +0.03 | −0.17 | +0.20 | +.149 | −.0070 | −.017 | +.085 | −.102 |

ment being greater than the maximum increase that occurred in experiment No. 1. These results are in conformity with those obtained in the autolysis experiment.

Slight apparent decreases, which for the present must be regarded as due to possible inequalities in sampling, have taken place in the total phosphorus. On account of the effect of the decreases in total phosphorus upon the value of the other phosphorous compounds, changes in those constituents will be discussed in connection with Table 25.

Table 25 shows the distribution of nitrogen and phosphorus expressed as percentages of total nitrogen and total phosphorus.

The distribution of the nitrogen compounds does not differ greatly from that in case of experiment No. 1. There is an appreciable increase in the proportion of total nitrogen present as soluble, noncoagulable, proteose, and ammoniacal nitrogen, and a decrease in the proportion present as coagulable nitrogen.

Insoluble phosphorus shows appreciable decreases that range from 5.22 per cent in case of the rump to 8.58 per cent in case of the loin. These results appear to be in conformity with the findings obtained in the autolysis experiment, but in view of the results obtained in other experiments of this series this seeming conformity must be regarded as accidental.

Total soluble phosphorus shows increases corresponding to the decreases in insoluble phosphorus.

Soluble inorganic phosphorus shows appreciable increases, which range from 10.37 per cent in the case of the round to 23.47 per cent in the case of the loin. On the whole the increases in soluble inorganic phosphorus are but slightly greater than similar changes in this constituent in Experiment No. 1. On account of the much longer storage period in Experiment No. 2 a larger increase in inorganic phosphorus might have been expected; but in this connection it is interesting to note that the material used for this experiment already contained a considerably higher percentage of preformed inorganic phosphorus than did the material used in the first experiment. It would appear as though the larger quantity of inorganic phosphorus present in the material used in the second experiment either of itself retarded the rate of change of organic phosphorus into inorganic forms or was indicative of some retarding agency.

Interesting light is thrown on this question by the results of the autolysis experiment, as shown in Table 11, where under the heading "Inorganic phosphorus" it may be noted that the increase in this constituent takes place most rapidly during the first 7 days of the experiment. Thus during the first 7 days the relative increase amounts to 52.78 per cent, while during the total incubation period of 100 days the relative increase amounts to only 65.27 per

cent, so that 80.9 per cent of the total increase in inorganic phosphorus has taken place in the first 7 days and 19.1 per cent in the remaining 93 days. These facts indicate very clearly that the rate of the enzymatic change of organic phosphorus to inorganic forms decreases as the reaction progresses. It is, therefore, not surprising that the cleavage of the organic phosphorus took place rather slowly in this experiment where the phosphorus distribution in the material used approximated to that obtaining in meat which has already undergone a certain amount of autolysis. The exact cause of the retarded rate of change, however, remains to be determined.

Soluble organic phosphorus shows large relative decreases that vary from 36.89 per cent in the case of the round to 54.10 per cent in the case of the loin. However, the actual decreases are only slightly greater than those observed in the carcass stored for two weeks in Experiment No. 1. The apparent explanation for the slower rate of change of organic phosphorus into inorganic forms has already been discussed under inorganic phosphorus.

## EXPERIMENT NO. 3.

### HISTORY OF CARCASS.

A "grade" shorthorn steer 4½ years old and of fair conformation and finish, was slaughtered in the usual manner and the carcass was allowed to hang for 50 minutes on the killing floor, after which it was run into the cooler. The warm carcass weighed 755 pounds. The carcass was held for 22 hours in the fore cooler at a temperature between 30° and 36° F., and for 48 hours in the main cooler at a temperature varying from 30° to 32° F. The humidity of the fore cooler was 95 per cent and that of the main cooler 98 per cent of saturation. After storage for 70 hours in the packing-house coolers the two hind quarters of the carcass were carefully wrapped and transported to the bureau's cold-storage rooms, the trip requiring less than one hour.

### STORAGE.

The quarters of beef were unwrapped and weighed, and one was immediately prepared for analysis while the other was hung up in cold-storage room No. 1 for a period of 42 days.

The temperature of the cold-storage room was fairly uniform throughout this experiment, ranging from 32° to 36° F. The humidity varied from 69 to 74 per cent of saturation.

Observations as to the condition of the beef were made at intervals during the storage period, with the following results:

After 24 days in storage the beef was in good condition. There was a slight growth of mold on the outside and inside of the flank. The exposed cut muscular surfaces on the inside of the round and on the tip of the loin had become dark-brown in color and firm in

textures. Exposed bundles of muscles at the shank had turned dark-brown in color.

After 31 days in storage the condition of the meat had not changed appreciably since the previous observation, except perhaps that evidences of desiccation had become more apparent.

At the end of the storage period of 42 days in the bureau's cooler, or after a total period of 45 days in cold storage, the beef was in good condition as regards state of preservation although it showed considerable drying out, particularly where the meat was not well covered with fat. There was also a slight growth of mold on the flank and "hanging tender" and a slightly musty odor at these points. The beef showed a shrinkage of 6.3 per cent during storage.

### QUALITY OF MEAT.

*Fresh quarter, in storage 71 hours.*—This quarter was of fairly good quality as regards conformation and finish, being fairly well covered with fat, and would have been classed as "good." The judge's opinions regarding the quality of the broiled test steak cut from this quarter are as follows:

Mr. A.—The tenderloin is tender and of good flavor. The loin portion is much tougher than the tenderloin, while the flank end is too tough too eat. As a whole the steak has a good flavor.

Mr. B.—The steak is more tender than that from the corresponding quarter of carcass No. 2, but is less tender than that from carcass No. 1. The flavor is not as good as that of the steaks from the quarters of beef just described. As regards tenderness and palatability, the tenderloin ranks first and the flank end last.

Mr. C.—On the whole the steak is superior to the one from the corresponding quarter of carcass No. 2, but inferior to the one from carcass No. 1. The steak has a good flavor. The tenderloin is the most tender and the flank end the least so of the different parts of the steak.

*Quarter of beef stored 45 days.*—When the quarter of beef was cut up preparatory to analysis, the cut surface at the butt of the round was found to be bright-red in color except for a narrow dark band at the surface where the muscular tissue had been exposed to the air. Where the surface of the meat had been covered with fat there was only a trace of such a band. The freshly cut surface of the meat had an odor that was rather different from that of fresh meat and which might have been termed slightly "old," but which was in no sense an odor of putrefaction. When the loin was cut, it was found that the tenderloin was somewhat darkened around the outside and had a slightly "off" odor. The porterhouse steak cut for broiling had a rather "old" odor, particularly at the outer portion of the tenderloin and at the flank end where the odor was that of incipient putrefaction. On being cut and ground, the meat appeared to be comparatively tender. The kidney fat had a distinctly "old" and sour odor.

On the whole, this quarter of beef, which has been held in cold storage for a total period of 45 days, appeared to be in sound condition; but the market value of the beef was probably less than it would have been earlier in the storage period, principally because of the effects of desiccation upon the appearance of the meat. The organoleptic qualities of the broiled test steak cut from this quarter were reported upon by the respective judges as follows:

Mr. A.—The tenderloin portion is fairly tender and has a good flavor, except the outer portion, which has a rather "old" taste. The loin portion is fairly tender, but rather dry and lacking in flavor. Portions have an "old" taste. The flank end is tough and stringy and the flavor is not good.

Mr. B.—The steak is generally superior to the one cut from the corresponding quarter at the beginning of the storage period as regards tenderness, but inferior as regards flavor. Portions of the steak, particularly outer portions of the tenderloin and loin, are tainted and not edible. This "old" flavor might be called "gamey."

Mr. C.—This steak shows some signs of incipient putrefaction at the flank end and on the outside of the tenderloin. Changes are positive but not extensive. The tenderloin is quite tender and fairly juicy, but has an "old" flavor, and portions have a slightly "off" flavor.

### CHEMICAL EXAMINATION OF CARCASS NO. 3.

Tables 26 to 32, inclusive, show the changes which took place in the composition of carcass No. 3 during 42 days of cold storage.

Table 26 shows the composition of the carcass expressed in terms of percentages of fresh material; but for reasons previously noted these data will not be discussed.

Table 27 shows the composition of the material expressed as percentages of moisture-free and fat-free material.

There are appreciable losses of moisture, which are slightly greater than similar losses observed in the case of the carcass stored 28 days.

There are slight changes in the ash, which have no significance.

The data for total nitrogen show appreciable losses, the significance of which is not yet apparent.

Changes in ammonia and in phosphorus compounds will be discussed in connection with Tables 31 and 32.

TABLE 26.—*Composition expressed in terms of percentage of fresh material.*

| Serial No. | Description of sample. | Storage period. | Moisture. | Fat. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total. | Soluble. | Insoluble. |
| | | *D. H.* | | | | | | | | |
| 19 | Round: Right hind quarter. | 2 23 | 74.59 | 2.06 | 1.09 | 3.46 | 0.0102 | 0.209 | 0.163 | 0.046 |
| 38 | Round: Left hind quarter... | 44 23 | 74.15 | 1.96 | 1.11 | 3.48 | .0122 | .211 | .165 | .046 |
| 20 | Rump: Right hind quarter.. | 2 23 | 73.79 | 3.19 | 1.06 | 3.39 | .0102 | .203 | .157 | .046 |
| 39 | Rump: Left hind quarter... | 44 23 | 73.32 | 3.27 | 1.06 | 3.36 | .0116 | .198 | .148 | .050 |
| 21 | Loin: Right hind quarter... | 2 23 | 73.50 | 4.17 | 1.03 | 3.30 | .0094 | .194 | .152 | .042 |
| 40 | Loin: Left hind quarter..... | 44 23 | 71.82 | 4.92 | 1.09 | 3.36 | .0115 | .197 | .149 | .048 |

TABLE 28.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* *H.* | | | | | | | | | | | | |
| 19 | Round: Right hind quarter | 2 23 | 6.96 | 1.19 | 5.77 | 0.77 | 0.947 | 0.514 | 0.433 | 0.029 | 0.0871 | 0.163 | 0.103 | 0.060 |
| 38 | Round: Left hind quarter | 44 23 | 7.25 | .86 | 6.39 | .85 | 1.01 | .487 | .523 | .063 | .1208 | .165 | .135 | .030 |
| 20 | Rump: Right hind quarter | 2 23 | 6.99 | .99 | 6.00 | .70 | .958 | .531 | .427 | .031 | .0852 | .157 | .098 | .059 |
| 39 | Rump: Left hind quarter | 44 23 | 7.07 | .66 | 6.41 | .74 | .988 | .477 | .511 | .062 | .1203 | .148 | .125 | .023 |
| 21 | Loin: Right hind quarter | 2 23 | 6.81 | .98 | 5.83 | .71 | .950 | .529 | .421 | .027 | .0848 | .152 | .094 | .058 |
| 40 | Loin: Left hind quarter | 44 23 | 7.01 | .76 | 6.25 | .70 | .996 | .519 | .477 | .054 | .1144 | .149 | .127 | .022 |

TABLE 29.—*Composition of 0.9 per cent sodium chlorid extract of meat, expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* *H.* | | | | | | | | | | | | |
| 19 | Round: Right hind quarter | 2 23 | 29.81 | 5.10 | 24.71 | 3.28 | 4.06 | 2.20 | 1.86 | 0.125 | 0.3731 | 0.698 | 0.441 | 0.257 |
| 38 | Round: Left hind quarter | 44 23 | 30.34 | 3.58 | 26.76 | 3.54 | 4.23 | 2.04 | 2.19 | .261 | .5055 | .691 | .565 | .126 |
| | Change | 42 | +0.53 | −1.52 | +2.05 | +0.26 | +0.17 | −0.16 | +0.33 | +.136 | +.1324 | −.007 | +.124 | −.131 |
| 20 | Rump: Right hind quarter | 2 23 | 30.34 | 4.28 | 26.06 | 3.02 | 4.16 | 2.31 | 1.85 | .134 | .3702 | .680 | .428 | .252 |
| 39 | Rump: Left hind quarter | 44 23 | 30.20 | 2.82 | 27.38 | 3.14 | 4.22 | 2.04 | 2.18 | .263 | .5138 | .631 | .535 | .096 |
| | Change | 42 | −0.14 | −1.46 | +1.32 | +0.12 | +0.06 | −0.27 | +0.33 | +.129 | +.1436 | −.049 | +.107 | −.156 |
| 21 | Loin: Right hind quarter | 2 23 | 30.48 | 4.37 | 26.11 | 3.18 | 4.26 | 2.37 | 1.89 | .123 | .3798 | .682 | .420 | .262 |
| 40 | Loin: Left hind quarter | 44 23 | 30.14 | 3.27 | 26.87 | 3.01 | 4.28 | 2.23 | 2.05 | .233 | .4918 | .643 | .545 | .098 |
| | Change | 42 | −0.34 | −1.10 | +0.76 | −0.17 | +0.02 | −0.14 | +0.16 | +.110 | +.1120 | −.039 | +.125 | −.164 |

TABLE 31.—*Distribution of nitrogen and phosphorus on basis of 100 parts of the respective constituents at beginning of storage period.*

| Serial No. | Description of sample. | Storage period. | | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluable. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | D. | H. | | | | | | | | | | | | |
| 19 | Round: Right hind quarter | 2 | 23 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 38 | Round: Left hind quarter | 44 | 23 | 98.51 | 104.19 | 92.73 | 117.74 | 208.80 | 135.48 | 117.24 | 98.71 | 98.00 | 98.91 | 128.14 | 48.87 |
| 20 | Rump: Right hind quarter | 2 | 23 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 39 | Rump: Left hind quarter | 44 | 23 | 97.22 | 101.44 | 88.31 | 117.84 | 196.27 | 138.79 | 111.01 | 95.79 | 106.24 | 92.69 | 125.19 | 37.69 |
| 21 | Loin: Right hind quarter | 2 | 23 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 40 | Loin: Left hind quarter | 44 | 23 | 97.83 | 100.47 | 94.09 | 108.47 | 189.43 | 129.49 | 117.86 | 97.34 | 108.87 | 94.19 | 129.78 | 37.27 |

TABLE 32.—*Distribution of nitrogen and phosphorus, expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. | | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluable. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | D. | H. | | | | | | | | | | | | |
| 19 | Round: Right hind quarter | 2 | 23 | 100.00 | 27.43 | 14.86 | 12.57 | 0.845 | 2.52 | 0.294 | 100.00 | 21.81 | 78.19 | 49.36 | 28.83 |
| 38 | Round: Left hind quarter | 44 | 23 | 100.00 | 29.01 | 13.99 | 15.02 | 1.790 | 3.47 | .350 | 100.00 | 21.66 | 78.34 | 64.07 | 14.24 |
| | Change, per cent | 42 | | 0.00 | +5.76 | −5.87 | +19.51 | +111.95 | +37.53 | +19.00 | 0.00 | − .69 | + .19 | +29.80 | −50.61 |
| 20 | Rump: Right hind quarter | 2 | 23 | 100.00 | 28.24 | 15.68 | 12.56 | .910 | 2.51 | .302 | 100.00 | 22.90 | 77.10 | 48.47 | 28.63 |
| 39 | Rump: Left hind quarter | 44 | 23 | 100.00 | 29.47 | 14.24 | 15.23 | 1.837 | 3.59 | .345 | 100.00 | 25.39 | 74.61 | 63.35 | 11.26 |
| | Change, per cent | 42 | | 0.00 | +4.35 | −9.16 | +21.20 | +101.89 | +42.76 | +14.19 | 0.00 | +10.87 | −3.23 | +30.70 | −60.71 |
| 21 | Loin: Right hind quarter | 2 | 23 | 100.00 | 28.88 | 16.07 | 12.81 | .834 | 2.58 | .285 | 100.00 | 21.42 | 78.58 | 48.35 | 30.23 |
| 40 | Loin: Left hind quarter | 44 | 23 | 100.00 | 29.66 | 15.45 | 14.21 | 1.615 | 3.41 | .343 | 100.00 | 23.97 | 76.03 | 64.46 | 11.57 |
| | Change, per cent | 42 | | 0.00 | +2.70 | −3.82 | +10.86 | + 93.63 | +32.36 | +20.38 | 0.00 | +11.91 | −3.25 | +33.32 | −61.73 |

saturation. After storage for 70 hours in the packing-house coolers, the hind quarters of the carcass were carefully wrapped and transported to the bureau's cooler, the trip requiring less than an hour.

### STORAGE.

The quarters of beef were unwrapped and weighed; one quarter was hung up in cold-storage room No. 1 for a period of 63 days; the other was prepared immediately for analysis.

The temperature of the cold-storage room was fairly uniform, ranging between 34° and 37° F. during the greater part of the experiment. On one occasion, for a period of about a day, the temperature ran up to 40° F. owing to difficulties with the refrigerating equipment. The humidity of the cold-storage room ranged from 69.5 to 73.5 per cent of saturation, except that when the temperature rose to 40° F. the humidity was increased to 82 per cent by the melting of the ice from the coils.

While observations as to the condition of the beef in storage were made at approximately weekly intervals during the storage period, only a few of the observations will be reported.

After 24 days in storage the quarter of beef was in normal condition. The flank showed slight desiccation and a trace of mold. At the end of 38 days in storage the beef was in very good condition. There was a slight growth of mold on the exposed muscular tissue at the inside of the butt of the round and a trace only on the flank, which had become rather hard and dry. After 52 days in storage the beef had begun to look rather old and showed considerable desiccation, particularly the flank, which had become quite hard and dry. There was a very slight growth of mold on the flank. The beef had a rather "old" odor, but not that of putrefaction.

At the end of the storage period, or after storage for 63 days in the bureau's cooler, the quarter of beef had practically the same appearance as noted at the end of 52 days in storage. An experienced meat inspector whose daily work brought him in contact with chilled beef as it is handled on the market examined this quarter of beef at the end of the storage period and stated that he considered it to be in first-class condition.

### QUALITY OF MEAT.

*Fresh quarter, stored 73 hours.*—This quarter was of fairly good quality as regards form and finish and was well covered with fat, except a portion toward the shank. As regards market classification the quarter would have been classed "good." The broiled test steak cut from this quarter was described by the respective judges as follows:

Mr. A.—The tenderloin is quite tender, the loin portion rather tough, and the flank end very tough. The steak is juicy and has a good flavor.

Table 33 shows the composition of the carcass expressed in terms of percentages of the fresh material.

Table 34 shows the composition of the carcass expressed in terms of percentages of the moisture-free and fat-free material.

There are appreciable losses of moisture which are somewhat greater, on the whole, than those observed in the case of carcass No. 3, stored 42 days.

Slight changes in the ash are without significance.

The data for total nitrogen seem to show appreciable decreases in this constituent. The fact that similar, though smaller, decreases were noted in the nitrogen content of carcasses Nos. 2 and 3, stored for 28 and 42 days, respectively, makes it appear that these apparent losses of nitrogen from the meat during storage may have some significance.

TABLE 33.—*Composition expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | | Moisture. | Fat. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Total. | Soluble. | Insoluble. |
| | | *D.* | *H.* | | | | | | | | |
| 31 | Round: Right hind quarter. | 3 | 1 | 74.51 | 2.85 | 1.06 | 3.52 | 0.0103 | 0.202 | 0.156 | 0.046 |
| 50 | Round: Left hind quarter... | 65 | 22 | 73.40 | 3.15 | 1.07 | 3.51 | .0134 | .199 | .157 | .042 |
| 32 | Rump: Right hind quarter . | 3 | 1 | 73.01 | 4.77 | 1.04 | 3.30 | .0100 | .197 | .150 | .047 |
| 51 | Rump: Left hind quarter... | 65 | 22 | 71.50 | 5.73 | 1.04 | 3.37 | .0132 | .186 | .145 | .041 |
| 33 | Loin: Right hind quarter... | 3 | 1 | 71.37 | 6.98 | .99 | 3.28 | .0092 | .189 | .144 | .045 |
| 52 | Loin: Left hind quarter...... | 65 | 22 | 70.10 | 7.41 | 1.06 | 3.31 | .0115 | .181 | .136 | .045 |
| 34 | Flank: Right hind quarter.. | 3 | 1 | 71.56 | 5.81 | 1.02 | 3.51 | .0088 | .184 | .148 | .031 |
| 53 | Flank: Left hind quarter... | 65 | 22 | 55.49 | 13.37 | 1.39 | 4.72 | .0178 | .237 | .186 | .056 |

TABLE 34.—*Composition expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | | Moisture, fat-free basis. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total. | Soluble. | Insoluble. |
| | | *D.* | *H.* | | | | | | | |
| 31 | Round: Right hind quarter. | 3 | 1 | 76.69 | 4.68 | 15.53 | 0.0452 | 0.891 | 0.687 | 0.204 |
| 50 | Round: Left hind quarter... | 65 | 22 | 75.78 | 4.56 | 14.96 | .0572 | .849 | .667 | .182 |
| | Change................ | 62 | 21 | − 0.91 | − 0.12 | − 0.57 | + .0120 | − .042 | − .020 | − .022 |
| 32 | Rump: Right hind quarter.. | 3 | 1 | 76.67 | 4.66 | 14.86 | .0449 | .887 | .675 | .212 |
| 51 | Rump: Left hind quarter... | 65 | 22 | 75.84 | 4.57 | 14.77 | .0580 | .818 | .637 | .181 |
| | Change................ | 61 | 21 | − 0.83 | − 0.09 | − 0.09 | + .0131 | − .069 | − .038 | − .031 |
| 33 | Loin: Right hind quarter.... | 3 | 1 | 76.73 | 4.57 | 15.15 | .0425 | .871 | .664 | .207 |
| 52 | Loin: Left hind quarter..... | 65 | 22 | 75.70 | 4.69 | 14.71 | .0513 | .806 | .605 | .201 |
| | Change................ | 62 | 21 | − 1.03 | + 0.12 | − 0.44 | + .0088 | − .065 | − .059 | − .006 |
| 34 | Flank: Right hind quarter.. | 3 | 1 | 75.97 | 4.51 | 15.49 | .0390 | .811 | .654 | .157 |
| 53 | Flank: Left hind quarter.... | 65 | 22 | 64.05 | 4.45 | 15.16 | .0572 | .762 | .597 | .165 |
| | Change................ | 62 | 21 | −11.92 | − 0.06 | − 0.33 | + .0182 | − .049 | − .057 | + .008 |

TABLE 35.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* | *H.* | | | | | | | | | | | | |
| 31 | Round: Right hind quarter | 3 | 1 | 7.65 | 1.01 | 6.64 | 0.64 | 1.12 | 0.700 | 0.420 | 0.038 | 0.0896 | 0.156 | 0.129 | 0.027 |
| 50 | Round: Left hind quarter | 65 | 22 | 7.62 | .97 | 6.65 | .74 | 1.12 | .566 | .554 | .048 | .1434 | .157 | .150 | .007 |
| 32 | Rump: Right hind quarter | 3 | 1 | 7.37 | .92 | 6.45 | .63 | 1.07 | .646 | .424 | .039 | .0883 | .150 | .121 | .029 |
| 51 | Rump: Left hind quarter | 65 | 22 | 7.47 | .90 | 6.57 | .70 | 1.08 | .574 | .506 | .050 | .1456 | .145 | .132 | .013 |
| 33 | Loin: Right hind quarter | 3 | 1 | 7.46 | .96 | 6.50 | .61 | 1.08 | .661 | .419 | .035 | .0847 | .144 | .118 | .026 |
| 52 | Loin: Left hind quarter | 65 | 22 | 7.25 | .80 | 6.45 | .64 | 1.07 | .561 | .509 | .044 | .1386 | .136 | .129 | .007 |
| 34 | Flank: Right hind quarter | 3 | 1 | 7.44 | 1.01 | 6.43 | .65 | 1.08 | .687 | .393 | .030 | .0816 | .148 | .127 | .021 |
| 53 | Flank: Left hind quarter | 65 | 22 | 9.04 | .87 | 8.17 | .86 | 1.36 | .725 | .635 | .044 | .1572 | .186 | .176 | .010 |

TABLE 36.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* | *H.* | | | | | | | | | | | | |
| 31 | Round: Right hind quarter | 3 | 1 | 33.77 | 4.44 | 29.33 | 2.83 | 4.95 | 3.09 | 1.86 | 0.166 | 0.3959 | 0.687 | 0.571 | 0.116 |
| 50 | Round: Left hind quarter | 65 | 22 | 32.48 | 4.11 | 28.37 | 3.13 | 4.76 | 2.41 | 2.35 | .204 | .6114 | .667 | .637 | .030 |
| | Change | 62 | 21 | −1.29 | −0.33 | −0.96 | +0.30 | −0.19 | −0.68 | +0.49 | + .038 | + .2155 | − .020 | + .066 | − .086 |
| 32 | Rump: Right hind quarter | 3 | 1 | 33.17 | 4.14 | 29.03 | 2.83 | 4.80 | 2.91 | 1.89 | .167 | .3973 | .675 | .542 | .133 |
| 51 | Rump: Left hind quarter | 65 | 22 | 32.79 | 3.93 | 28.86 | 3.05 | 4.72 | 2.52 | 2.20 | .218 | .6393 | .637 | .579 | .058 |
| | Change | 62 | 21 | −0.38 | −0.21 | −0.17 | +0.22 | −0.08 | −0.39 | +0.31 | + .051 | + .2420 | − .038 | + .037 | − .075 |
| 33 | Loin: Right hind quarter | 3 | 1 | 34.46 | 4.41 | 30.05 | 2.82 | 4.97 | 3.05 | 1.92 | .161 | .3912 | .664 | .544 | .120 |
| 52 | Loin: Left hind quarter | 65 | 22 | 32.23 | 3.56 | 28.67 | 2.84 | 4.76 | 2.50 | 2.26 | .195 | .6161 | .605 | .572 | .033 |
| | Change | 62 | 21 | −2.23 | −0.85 | −1.38 | +0.02 | −0.21 | −0.55 | +0.34 | + .034 | + .2249 | − .059 | + .028 | − .087 |
| 34 | Flank: Right hand quarter | 3 | 1 | 32.88 | 4.47 | 28.41 | 2.88 | 4.77 | 3.04 | 1.73 | .133 | .3606 | .654 | .560 | .094 |
| 53 | Flank: Left hind quarter | 65 | 22 | 29.02 | .280 | 26.22 | 2.75 | 4.35 | 2.33 | 2.02 | .141 | .5048 | .597 | .565 | .032 |
| | Change | 62 | 21 | −3.86 | −1.67 | −2.19 | −0.13 | −0.42 | −0.71 | +0.29 | + .008 | + .1442 | − .057 | + .005 | − .062 |

Table 35 shows the composition of the 0.9 per cent sodium chlorid extract of the meat expressed in terms of percentages of the fresh material.

Table 36 shows the composition of the sodium chlorid extract expressed in terms of percentages of moisture-free and fat-free material.

The data for total solids show appreciable decreases in this constituent. It will be recalled that carcasses Nos. 1 and 2, stored for 14 and 28 days, respectively, show smaller but appreciable decreases in total solids, while carcass No. 3, stored for 42 days, showed irregular changes.

Changes in the ash are in the nature of appreciable decreases, which, in large part, may be accounted for by the similar but smaller decreases in total soluble phosphorus, as will be seen if the changes in soluble phosphorus are calculated in terms of normal potassium phosphate.

Organic extractives show decreases similar to but smaller than those noted in the case of total solids.

In the acidity of the samples there are appreciable but not large increases, which would be slightly larger if correction is made for the increases in ammonia.

Table 37 shows the changes in the composition of the fat during storage.

Slight changes in the iodin numbers and refractive indices are without significance.

There are marked increases in the acidity of the kidney and the external fats and an appreciable increase in that of the intermuscular fat. Each of these increases is greater than the corresponding increase in carcass No. 3 stored for 42 days. The kidney and external fats were of very poor quality and the intermuscular fat was of fair quality.

TABLE 37.—*Composition of fat.*

| Serial No. | Description of sample. | Storage period. | | Iodin number. | Refractive index 40° C. | Per cent acidity as oleic acid. | Rancidity. | Physical characters. |
|---|---|---|---|---|---|---|---|---|
| | | *D.* | *H.* | | | | | |
| 35 | Kidney fat: Right hind quarter.. | 3 | 1 | 40.85 | 1.4562 | 0.28 | Neg..... | Normal. |
| 54 | Kidney fat: Left hind quarter.... | 65 | 22 | 41.93 | 1.4568 | 4.79 | ...do.... | Strong flavor and odor. |
| 36 | Intermuscular fat: Right hind quarter. | 3 | 1 | 50.44 | 1.4570 | .28 | ...do.... | Normal. |
| 55 | Intermuscular fat: Left hind quarter. | 65 | 22 | 50.63 | 1.4572 | 1.47 | ...do.... | Fair quality. |
| 37 | External fat: Right hind quarter. | 3 | 1 | 57.53 | 1.4576 | .23 | ...do.... | Normal. |
| 56 | External fat: Left hind quarter... | 65 | 22 | 55.89 | 1.4578 | 3.55 | ...do.... | Strong flavor and odor; not so pronounced as No. 54. |

TABLE 38.—*Distribution of nitrogen and phosphorus on basis of 100 parts of the respective constituents at beginning of storage period.*

| Serial No. | Description of sample. | Storage period. D. | Storage period. H. | Nitrogen. Total. | Nitrogen. Soluble. | Nitrogen. Coagulable. | Nitrogen. Non-coagulable. | Nitrogen. Proteose. | Nitrogen. Amino. | Nitrogen. Ammoniacal. | Phosphorus. Total. | Phosphorus. Insoluble. | Phosphorus. Soluble. | Phosphorus. Soluble inorganic. | Phosphorus. Soluble organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Round: Right hind quarter | 3 | 1 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 50 | Round: Left hind quarter | 65 | 22 | 96.33 | 96.16 | 77.99 | 126.34 | 122.89 | 154.43 | 126.55 | 95.31 | 89.21 | 97.12 | 111.65 | 25.67 |
| 32 | Rump: Right hind quarter | 3 | 1 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 51 | Rump: Left hind quarter | 65 | 22 | 99.39 | 98.33 | 86.60 | 116.40 | 130.39 | 160.91 | 129.18 | 92.21 | 85.60 | 94.28 | 106.73 | 43.41 |
| 33 | Loin: Right hind quarter | 3 | 1 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 52 | Loin: Left hind quarter | 65 | 22 | 97.10 | 95.77 | 81.97 | 117.71 | 121.12 | 157.49 | 120.71 | 92.56 | 97.14 | 91.13 | 105.20 | 27.27 |
| 34 | Flank: Right hind quarter | 3 | 1 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 53 | Flank: Left hind quarter | 65 | 22 | 97.87 | 91.19 | 76.64 | 116.76 | 106.01 | 139.99 | 146.67 | 93.90 | 105.29 | 91.17 | 100.93 | 33.12 |

TABLE 39.—*Distribution of nitrogen and phosphorus, expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. D. | Storage period. H. | Nitrogen. Total. | Nitrogen. Soluble. | Nitrogen. Coagulable. | Nitrogen. Non-coagulable. | Nitrogen. Proteose. | Nitrogen. Amino. | Nitrogen. Ammoniacal. | Phosphorus. Total. | Phosphorus. Insoluble. | Phosphorus. Soluble. | Phosphorus. Soluble inorganic. | Phosphorus. Soluble organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Round: Right hind quarter | 3 | 1 | 100.00 | 31.87 | 19.90 | 11.97 | 1.07 | 2.55 | 0.29 | 100.00 | 22.88 | 77.12 | 64.08 | 13.04 |
| 50 | Round: Left hind quarter | 65 | 22 | 100.00 | 31.82 | 16.11 | 15.71 | 1.36 | 4.09 | .38 | 100.00 | 21.42 | 78.58 | 75.08 | 3.50 |
| | Change | 62 | 21 | 0.00 | − .16 | −19.03 | +31.15 | +27.57 | +60.32 | +31.48 | 0.00 | −6.38 | +1.89 | +17.17 | −73.16 |
| 32 | Rump: Right hind quarter | 3 | 1 | 100.00 | 32.30 | 19.58 | 12.72 | 1.13 | 2.67 | .30 | 100.00 | 23.88 | 76.12 | 61.16 | 14.96 |
| 51 | Rump: Left hind quarter | 65 | 22 | 100.00 | 31.96 | 17.06 | 14.90 | 1.48 | 4.33 | .39 | 100.00 | 22.18 | 77.82 | 70.79 | 7.03 |
| | Change | 62 | 21 | 0.00 | −1.07 | −12.87 | +17.12 | +31.19 | + 61.89 | +30.06 | 0.00 | −7.12 | +2.24 | +15.75 | −53.01 |
| 33 | Loin: Right hind quarter | 3 | 1 | 100.00 | 32.81 | 20.13 | 12.68 | 1.06 | 2.58 | .28 | 100.00 | 23.73 | 76.27 | 62.49 | 13.78 |
| 52 | Loin: Left hind quarter | 65 | 22 | 100.00 | 32.36 | 17.00 | 15.36 | 1.33 | 4.19 | .35 | 100.00 | 24.91 | 75.09 | 71.04 | 4.05 |
| | Change | 62 | 21 | 0.00 | −1.36 | −15.58 | +21.22 | +24.74 | +62.20 | +24.30 | 0.00 | +4.97 | −1.55 | +13.68 | −70.61 |
| 34 | Flank: Right hind quarter | 3 | 1 | 100.00 | 30.79 | 19.63 | 11.16 | .86 | 2.33 | .25 | 100.00 | 19.34 | 80.66 | 69.05 | 11.61 |
| 53 | Flank: Left hind quarter | 65 | 22 | 100.00 | 28.69 | 15.37 | 13.32 | .93 | 3.33 | .38 | 100.00 | 21.70 | 78.30 | 74.21 | 4.09 |
| | Change | 62 | 21 | 0.00 | −6.82 | −21.69 | +19.30 | +8.32 | +43.03 | +49.75 | 0.00 | +12.20 | −2.93 | +7.47 | −64.77 |

ing equipment. Temperature conditions were not so satisfactory as in previous experiments, and as a consequence the time that it was posssible to carry this quarter of beef in cold storage was probably shorter than it otherwise would have been. The humidity of the cold-storage room ranged from 70 to 82 per cent.

Observations as to the condition of the beef during storage were made at approximately weekly intervals, but only a few of them will be reported.

After 25 days in cold storage the beef was in good condition and showed no evidences of deterioration. At the end of 53 days in cold storage the beef was in generally good condition. There was a fairly heavy growth of mold on the inside of the flank. This part of the quarter had a rather strong odor, and in consequence of a poor circulation of air was rather damp. There was a slight growth of mold on the shank and on the exposed muscular tissue at the butt of the round. Except as noted above, the meat had no objectionable odor.

At the end of the storage period, or after 74 days in the bureau's cold-storage room, and after a total storage period of 77 days, the quarter of beef had a generally old and stale appearance. The external and kidney fat had turned dark in color and had a rather strong odor. The flank was dry and hard. There was practically no growth of mold on the meat. The beef had a rather "old" but not putrefactive odor.

A veterinary inspector familiar with the commercial handling of chilled beef pronounced the quarter of beef to be in good marketable condition, and stated that in his opinion the beef would have kept a couple of months longer in cold storage. The quarter of beef showed a shrinkage of 7.47 per cent at the end of the storage period.

### QUALITY OF MEAT,

*Fresh quarter, stored 70 hours.*—This quarter of beef was of very high grade both as regards form and finish, and was superior to any of the quarters previously used in these experiments. It was exceedingly well covered with fat, even well down on the shank; but the covering of fat was not excessive. This quarter would have been classed as "prime" beef. The organoleptic properties of the broiled test steak were described by the judges as follows:

Mr. B.—The steak has an excellent flavor and is as tender as any of the previously examined steaks that were cut from fresh quarters of beef. The tenderloin is fairly tender; the loin portion is rather tough; and the flank end is quite tough and stringy and hard to masticate.

Mr. C.—All portions of the steak are juicy and have an excellent flavor. The tenderloin is quite tender, the loin portion is a trifle tough, and the flank end is coarse, tough, and rubbery.

There are slight apparent decreases in the ash which are accompanied by decreases in total phosphorus.

Changes in nitrogen and phosphorus compounds will be discussed in connection with Tables 45 and 46.

TABLE 40.—*Composition expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Moisture. | Fat. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. Total. | Phosphorus. Soluble. | Phosphorus. Insoluble. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | D. H. | | | | | | | | |
| 44 | Round: Left hind quarter... | 2 22 | 73.15 | 3.15 | 1.08 | 3.45 | 0.0101 | 0.206 | 0.149 | 0.057 |
| 69 | Round: Right hind quarter. | 76 21 | 71.27 | 3.30 | 1.11 | 3.58 | .0133 | .206 | .163 | .043 |
| 45 | Rump: Left hind quarter... | 2 22 | 72.33 | 4.87 | 1.05 | 3.32 | .0094 | .195 | .153 | .042 |
| 70 | Rump: Right hind quarter. | 76 21 | 69.90 | 5.89 | 1.06 | 3.47 | .0128 | .198 | .152 | .046 |
| 46 | Loin: Left hind quarter...... | 2 22 | 72.06 | 5.34 | 1.03 | 3.36 | .0083 | .190 | .144 | .046 |
| 71 | Loin: Right hind quarter... | 76 21 | 69.63 | 5.80 | 1.08 | 3.44 | .0163 | .196 | .154 | .042 |

TABLE 41.—*Composition expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Moisture, fat-free material. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. Total. | Phosphorus. Soluble. | Phosphorus. Insoluble. |
|---|---|---|---|---|---|---|---|---|---|
| | | D. H. | | | | | | | |
| 44 | Round: Left hind quarter... | 2 22 | 75.53 | 4.54 | 14.54 | 0.0428 | 0.870 | 0.627 | 0.243 |
| 69 | Round: Right hind quarter.. | 76 21 | 73.70 | 4.37 | 14.08 | .0522 | .808 | .641 | .167 |
| | Change.................. | 73 23 | −1.83 | −0.17 | −0.46 | +.0094 | −.062 | +.014 | −.076 |
| 45 | Rump: Left hind quarter... | 2 22 | 76.03 | 4.61 | 14.54 | .0413 | .853 | .670 | .183 |
| 70 | Rump: Right hind quarter.. | 76 21 | 74.27 | 4.38 | 14.33 | .0528 | .816 | .627 | .189 |
| | Change.................. | 73 23 | −1.76 | −0.23 | −0.21 | +.0115 | −.037 | +.043 | +.006 |
| 46 | Loin: Right hind quarter.... | 2 22 | 76.13 | 4.56 | 14.85 | .0366 | .839 | .639 | .200 |
| 71 | Loin: Left hind quarter...... | 76 21 | 73.92 | 4.38 | 14.00 | .0665 | .797 | .626 | .171 |
| | Change.................. | 73 23 | −2.21 | −0.18 | −0.85 | +.0299 | −.042 | −.013 | −.029 |

Table 42 shows the composition of the 0.9 per cent sodium chlorid extract of the meat expressed in terms of percentages of the original material.

Table 43 shows the composition of the sodium chlorid extract of the meat expressed in terms of percentages of the moisture-free and fat-free material.

Changes in the total solids are irregular, but on the whole appreciable increases in this constituent have occurred. It is of interest to note that this is the first experiment in which there has been an increase in the total soluble solids of the meat during storage, previous experiments in which the meat had been stored for shorter periods of time having shown decreases in this constituent.

There are marked apparent decreases in the ash content of the round and rump, and a slight gain in that of the loin during storage. These large decreases must be regarded with suspicion.

On account of the suspicious character of the data for ash, positive value can not be assigned to those for organic extractives.

Increases in acidity are fairly marked and are greater than those which took place in any of the previous cold-storage experiments.

Table 44 shows the changes in the composition of the fat that took place during storage. The most important changes were very marked increases in the acidity of the external and the kidney fats, and an appreciable increase in that of the intermuscular fat. The increase in the acidity of the kidney fat was nearly twice as great, and that of the external fat was three times as great, as the corresponding increases in acidity in the preceding experiment. The increase in the acidity of the intermuscular fat was only slightly greater than in the preceding experiment. The kidney and external fats were of very poor quality, while the intermuscular fat was of fair quality.

TABLE 44.—*Composition of fat.*

| Serial No. | Description of sample. | Storage period. | Iodin number. | Refractive index 40°C. | Per cent acidity as oleic acid. | Rancidity. | Physical characters. |
|---|---|---|---|---|---|---|---|
| | | *D. H.* | | | | | |
| 47 | Kidney fat: Left hind quarter.... | 2 22 | 39.85 | 1.4562 | 0.34 | Neg..... | Normal. |
| 72 | Kidney fat: Right hind quarter.. | 76 21 | 38.21 | 1.4555 | 8.04 | ...do.... | Dark yellow; strong, sour odor; very strong flavor. |
| 48 | Intermuscular fat: Left hind quarter. | 2 22 | 44.70 | 1.4566 | .28 | ...do.... | Normal. |
| 73 | Intermuscular fat: Right hind quarter. | 76 21 | 44.63 | 1.4562 | 1.70 | ...do.... | Normal odor; comparatively sweet flavor. |
| 49 | External fat: Left hind quarter... | 2 22 | 50.76 | 1.4570 | .34 | ...do.... | Normal. |
| 74 | External fat: Right hind quarter. | 76 21 | 50.21 | 1.4560 | 10.86 | ...do.... | Dark yellow; strong, sour odor; strong disagreeable flavor. |

Table 45 shows the distribution of the nitrogen and the phosphorus upon the basis of 100 parts of the respective constituents in the meat at the beginning of the storage period.

There are appreciable decreases in total nitrogen that range from 5.72 per cent in the case of the loin to 1.44 per cent in the case of the rump. These data confirm the losses in total nitrogen that were observed in carcasses Nos. 2, 3, and 4; carcass No. 1 alone having shown slight apparent gains. The regular occurrence of a decrease in the total nitrogen content of the lean meat from 4 carcasses stored for periods ranging from 28 to 74 days would appear to indicate an actual loss of nitrogen from the meat during storage.

Fairly marked increases in the amount of total soluble nitrogen present in the meat have occurred during this storage period. These are the first appreciable increases in total soluble nitrogen that have taken place in any of the carcasses examined thus far. These data are in keeping with the previously noted increases in total solids in this experiment.

Coagulable nitrogen shows appreciable decreases, which are practically the same as those noted in the previous experiments. As has been previously noted, the data for coaguable nitrogen show merely the variations in the actual reserve amount of this constituent, and do not indicate the true extent of the transformation of coagulable proteins into noncoagulable forms, inasmuch as the supply of coagulable protein is being replenished from the insoluble protein at the same time as the coagulable protein is being transformed into noncoagulable compounds. The true extent of the change of coagulable protein into noncoagulable forms is shown in the data for noncoagulable nitrogen.

Increases in noncoagulable nitrogen, which range from 29.12 to 40.45 per cent, are much greater than the increases that took place in this constituent in the previous experiment.

Changes in proteose nitrogen are in the nature of increases, which are greater than those that took place in any of the previous experiments except Experiment No. 2.

The amino nitrogen almost doubled in the round and rump, and more than doubled in the loin during the storage period. The increases are larger than any corresponding increases that occurred in this constituent during the shorter periods of the previous experiments. The results are in continued conformity with the results of the autolysis experiment.

Ammoniacal nitrogen increased in each of the cuts analyzed. The increases in the round and rump, however, were not as great as the corresponding increases in Experiment No. 4, a fact which stands in no connection with the amounts of preformed ammonia in the material, but which must be accounted as a distinct exception to the rule that seems to have applied in most of these experiments. The increase in the loin, on the other hand, was the largest that had yet been observed in this constituent.

Changes in total phosphorus consisted in quite marked apparent decreases, the significance of which is not clear.

Table 46 shows the distribution of nitrogen and phosphorus expressed as percentages of total nitrogen and total phosphorus.

Soluble nitrogen makes up a smaller proportion of the total nitrogen of the fresh quarter of this carcass than it made in case of any fresh quarter previously examined.

Coagulable nitrogen forms a smaller proportion of the total nitrogen of the meat, both at the beginning and at the end of the storage

TABLE 45.—*Distribution of nitrogen and phosphorus on basis of 100 parts of the respective constituents at beginning of storage period.*

| Serial No. | Description of sample. | Storage period. | | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* | *H.* | | | | | | | | | | | | |
| 44 | Round: Left hind quarter | 2 | 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 69 | Round: Right hind quarter | 76 | 21 | 96.84 | 103.69 | 80.20 | 129.12 | 274.47 | 198.00 | 121.96 | 92.90 | 69.03 | 102.15 | 130.37 | 39.03 |
| 45 | Rump: Left hind quarter | 2 | 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 70 | Rump: Right hind quarter | 76 | 21 | 98.56 | 107.40 | 83.73 | 134.43 | 158.82 | 194.22 | 127.85 | 95.65 | 102.72 | 93.71 | 129.83 | 28.69 |
| 46 | Loin: Left hind quarter | 2 | 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 71 | Loin: Right hind quarter | 76 | 21 | 94.28 | 104.94 | 77.09 | 140.45 | 168.10 | 227.70 | 181.69 | 95.06 | 85.81 | 97.96 | 132.47 | 29.42 |

TABLE 46.—*Distribution of nitrogen and phosphorus, expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. | | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* | *H.* | | | | | | | | | | | | |
| 44 | Round: Left hind quarter | 2 | 22 | 100.00 | 26.07 | 13.55 | 12.52 | 0.647 | 2.71 | 0.294 | 100.00 | 27.94 | 72.06 | 49.79 | 22.27 |
| 69 | Round: Right hind quarter | 76 | 21 | 100.00 | 27.91 | 11.22 | 16.69 | 1.832 | 5.55 | .371 | 100.00 | 20.76 | 79.24 | 69.89 | 9.35 |
| | Change | 73 | 23 | 0.00 | + 7.08 | −17.18 | +33.34 | +183.43 | +104.47 | +25.96 | 0.00 | − 25.70 | +9.96 | +40.37 | −58.02 |
| 45 | Rump: Left hind quarter | 2 | 22 | 100.00 | 26.96 | 14.37 | 12.59 | .818 | 2.88 | .284 | 100.00 | 21.53 | 78.47 | 50.44 | 28.03 |
| 70 | Rump: Right hind quarter | 76 | 21 | 100.00 | 29.38 | 12.21 | 17.17 | 1.319 | 5.68 | .368 | 100.00 | 23.11 | 76.89 | 68.48 | 8.41 |
| | Change | 73 | 23 | 0.00 | + 8.97 | −15.04 | +36.40 | +61.15 | +97.07 | +29.62 | 0.00 | + 7.34 | −2.01 | +35.77 | −70.00 |
| 46 | Loin: Left hind quarter | 2 | 22 | 100.00 | 27.27 | 15.29 | 11.98 | .781 | 2.71 | .246 | 100.00 | 23.86 | 76.14 | 50.65 | 25.49 |
| 71 | Loin: Right hind quarter | 76 | 21 | 100.00 | 30.36 | 12.50 | 17.86 | 1.393 | 6.53 | .475 | 100.00 | 21.54 | 78.46 | 70.57 | 7.89 |
| | Change | 73 | 23 | 0.00 | +11.31 | −18.23 | +48.97 | +78.31 | +141.56 | +92.97 | 0.00 | − 9.72 | +3.05 | +39.33 | −69.05 |

while the humidity varied from 92 to 95 per cent of saturation. The humidity appears relatively high, yet the cooler was in apparently dry condition throughout the course of the experiment. There was no condensation of moisture on the walls or ceiling, and the surfaces of the carcasses were dry and firm. The circulation of air appeared to be excellent. The high humidity, apparently, was due to the continuous evaporation of moisture from the carcasses of beef held in cold storage.

After 20 days of storage the quarter of beef was in excellent condition and no growth of mold had appeared on the meat. At the end of 40 days of storage the beef was in fairly good condition. There was a light growth of mold over most of the quarter except on the top of the loin, where there was a heavy covering of fat. The growth of mold was heaviest on the cut end of the loin, on the exposed flank muscles, and on the under side of the loin. There was a slightly sour odor at the cut end of the loin. The meat was still in good marketable condition and would have needed but little trimming. After storage for 55 days the beef was in such condition that it was deemed inadvisable to carry it longer in cold storage. There was a heavy growth of mold over most of the quarter, except on the upper side of the loin, where there was a heavy covering of fat. There was a slightly "off" odor at the cut end of the loin, but practically no odor from the rest of the quarter. It showed a shrinkage of 3.27 per cent during storage. The quarter of beef was carefully wrapped and transported to the bureau's cold-storage room, where it was held a day longer at a temperature ranging from 34° to 48° F., after which it was prepared for analysis.

### QUALITY OF MEAT.

*Quarter of beef stored 66 hours.*—This quarter of beef was of fair quality and finish. The loin was well covered with fat, while the round, particularly about the shank, was only fairly well covered. There was a good but not an excessive deposit of kidney fat. The broiled test steak cut from this quarter was described by the judges as follows:

Mr. A.—The tenderloin is fairly tender, the loin portion is quite tough, and the flank end is very tough. The flavor of the steak is very good.

Mr. B.—The flavor of the steak is excellent. For a fresh steak it is fairly tender. The tenderloin is the most tender and the flank end the least so.

Mr. C.—The tenderloin is comparatively tender, the loin portion rather tough, and the flank end very tough and rubbery. The steak is juicy and has an excellent flavor.

*Quarter of beef stored 56 days, 18 hours.*—When the quarter of beef was cut up for analysis the cut surface at the butt of the round was found to have a bright-red color. Where the surface of the

TABLE 48.—*Composition expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Moisture, fat-free basis. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total. | Soluble. | Insoluble. |
| | | *D. H.* | | | | | | | |
| 82 | Round: Left hind quarter... | 2 18 | 77.17 | 4.75 | 15.00 | 0.0439 | 0.883 | 0.688 | 0.195 |
| 94 | Round: Right hind quarter. | 56 18 | 76.56 | 4.76 | 14.83 | .0462 | .871 | .677 | .194 |
| | Change................ | 54 | − 0.61 | + 0.01 | − 0.17 | + .0023 | − .012 | − .011 | − .001 |
| 83 | Rump: Left hind quarter... | 2 18 | 77.12 | 4.61 | 14.64 | .0434 | .885 | .669 | .216 |
| 95 | Rump: Right hind quarter.. | 56 18 | 77.11 | 4.78 | 14.84 | .0477 | .848 | .666 | .182 |
| | Change................ | 54 | − 0.01 | + 0.17 | + 0.20 | + .0043 | − .037 | − .003 | − .034 |
| 84 | Loin: Left hind quarter...... | 2 18 | 77.23 | 4.64 | 15.24 | .0410 | .876 | .663 | .213 |
| 96 | Loin: Right hind quarter.... | 56 18 | 76.42 | 4.56 | 14.89 | .0478 | .810 | .619 | .191 |
| | Change................ | 54 | − 0.81 | − 0.08 | − 0.35 | + .0068 | − .066 | − .044 | − .022 |

Table 49 shows the composition of the 0.9 per cent sodium chlorid extract of the meat expressed in terms of percentages of the original material.

Table 50 shows the composition of the meat expressed in terms of percentages of moisture-free and fat-free material.

The amount of total soluble solids present in the meat has increased considerably during the storage period. It is of interest to note in this connection that only one other carcass that has been examined thus far, viz, carcass No. 5, stored for 74 days, has shown appreciable increases in total soluble solids during storage. The increases that took place in this constituent in carcass No. 6 are greater than those which took place in carcass No. 5.

There are appreciable increases in ash of extract, the significance of which is not yet apparent.

Increases are observed in organic extractives that are similar to, but smaller than, the increases in total soluble solids.

Changes in the acidity of the meat during storage are irregular and without significance.

Table 51 shows the changes that took place in the composition of the fat during storage. The appreciable changes that appear to have taken place in the iodin absorption numbers of the samples are probably due to irregularities in the sampling of the fatty tissues rather than to actual changes in the iodin absorptive values of the fats.

The principal changes that took place in the fats during storage were fairly marked increases in the acidity of the kidney and external fats, and an appreciable increase in the acidity of the intermuscular fat. On the whole the increases in the acidity of the fats of this carcass are approximately equal to those that took place in this constituent in carcass No. 4, which was stored for 63 days in the bureau's cold-storage room.

TABLE 51.—*Composition of fat.*

| Serial No. | Description of sample. | Storage period. | Iodin number. | Refractive index 40°C. | Per cent acidity as oleic acid. | Rancidity. | Physical characters. |
|---|---|---|---|---|---|---|---|
| | | *D. H.* | | | | | |
| 85 | Kidney fat: Left hind quarter.... | 2 18 | 41.65 | 1.4560 | 0.34 | Neg..... | Normal. |
| 97 | Kidney fat: Right hind quarter.. | 56 18 | 39.38 | 1.4560 | 3.10 | ...do.... | Do. |
| 86 | Intermuscular fat: Left hind quarter. | 2 18 | 48.91 | 1.4570 | .28 | ...do.... | Do. |
| 98 | Intermuscular fat: Right hind quarter. | 56 18 | 49.42 | 1.4570 | 1.24 | ...do.... | Slight meaty odor and flavor. |
| 87 | External fat: Left hind quarter... | 2 18 | 53.60 | 1.4575 | .39 | ...do.... | Normal. |
| 99 | External fat: Right hind quarter.. | 56 18 | 56.75 | 1.4575 | 4.29 | ...do.... | Do. |

Table 52 shows the distribution of nitrogen and phosphorus upon the basis of 100 parts of the respective constituents in the meat at the beginning of the storage period.

Changes in total nitrogen are slight and irregular and are without significance.

Total soluble nitrogen shows fairly marked increases. This is the third experiment of this series where there has been an appreciable increase in the total soluble nitrogen in the meat during storage; the others have been Experiment No. 3, where the storage period was 44 days, and Experiment No. 5, where the storage period amounted to 74 days.

The changes in coagulable nitrogen consist in appreciable decreases, which are approximately equal to those that took place in carcass No. 1, stored for 14 days, but which are much smaller than those observed in carcasses Nos. 2 and 3, stored for 28 and 42 days, respectively.

Changes in noncoagulable nitrogen represent the true extent of the change of coagulable proteins into noncoagulable forms. Fairly marked increases are noted in this constituent, these increases being approximately equal to those observed in case of carcass No. 3, which had been stored for 42 days in the bureau's cold-storage room.

Proteose nitrogen shows very large relative increases, which are larger than those that took place in this constituent in any of the previous experiments of this series.

The increases in the amino nitrogen that occurred during this experiment are smaller throughout than the corresponding increases obtained in Experiment No. 3, where the storage period was 42 days in length. This is the first instance in this series of experiments in which the amino nitrogen has failed to show a continued increase when the cold-storage period was lengthened. This fact is probably due to the changed conditions of storage.

The average increase in ammoniacal nitrogen in this experiment is less than the average increase in Experiment No. 2, where the storage

period was but half as long; while each increase is less than the corresponding increase in Experiment No. 3, where the storage period was but three-fourths as long, and where the preformed ammonia was present in the original material in about the same quantity as in the present experiment.

Each portion of the stored quarter contained less total phosphorus than the corresponding portion of the fresh quarter. The significance of these apparent decreases is far from being clear.

Table 53 shows the distribution of nitrogen and phosphorus expressed as percentages of total nitrogen and total phosphorus.

The data for nitrogen do not demand special discussion.

Changes in insoluble phosphorus are of the usual irregular nature and their significance has not been established.

The changes in soluble inorganic phosphorus are in the nature of distinct increases. As regards the amount of preformed inorganic phosphorus that it contained, the fresh material is comparable to that used for Experiments Nos. 1 and 3. By comparing the increases in the inorganic phosphorus ratio in the same three experiments it is found that the increases during the 54-day storage period of the present experiment are greater, on the whole, than the corresponding increases effected by the shorter periods of storage of Experiments Nos. 1 and 3, the only exception being that the change in the round in this experiment is somewhat less than the corresponding change in Experiment No. 3. On the whole, the results are in conformity with those obtained in the autolysis experiment.

Changes in soluble organic phosphorus are of less significance than the corresponding changes in inorganic phosphorus.

## EXPERIMENT NO. 7.

### HISTORY OF CARCASS.

A "grade" Shorthorn steer 4 years old, rather rough in conformation and only fairly well finished, was slaughtered in the usual manner. The carcass was allowed to hang 1 hour on the killing floor, after which it was run into the fore cooler, where it was held 16 hours, and then into the main cooler, where it was held 51 hours at 30° F. The humidity of the fore cooler was 93 per cent and that of the main cooler 92 per cent of saturation. The weight of the warm carcass was 814 pounds. After storage in the packing-house coolers for a total period of 67 hours, the hind quarters were cut from the carcass, carefully wrapped, and transported to the bureau's cold-storage rooms, where one hind quarter was immediately prepared for analysis while the other was placed in cold-storage room No. 1, where it was held in storage.

### STORAGE.

The second quarter of beef was held in cold storage for an additional period of 177 days. The temperature of cold-storage room No. 1 remained fairly uniform, ranging between 32° and 36° F. during the larger part of the time. On a few occasions the temperature ran up to from 39° to 48° F. for a few hours at a time, in consequence of difficulties that were experienced with the refrigerating equipment, which finally necessitated the bringing of the experiment to a close. It is not considered that the rises in temperature that have been noted affected the value of the experiment appreciably; although the meat could have been held in cold storage for some time longer had these difficulties not been encountered. The humidity of the cold-storage room varied from 70 to 84 per cent of saturation. The following are a few of the observations that were made concerning the condition of the beef during storage:

After it had been 48 days in cold storage the quarter of beef was in generally good condition. The exposed flank and shank muscles had become darker in color and rather hard and dry in texture. There was a slight growth of mold on the cut muscular surfaces at the butt of the round and the tip of the loin.

At the end of 98 days of cold storage the beef was still in good condition. The color of the fat had changed from an original light yellow to a grayish white. There was a rather heavy growth of mold on the inside of the flank and lighter growths on the tip of the loin and on the exposed muscular tissue at the butt of the round. A slight odor was given off from the exposed, cut, muscular surfaces, but none was apparent from other parts of the quarter.

At the close of the storage period, or after a total period of 180 days of cold storage, the quarter of beef had a badly desiccated appearance, the flank being as hard as a board, and the muscles at the shank being hard, shrunken, and dark-brown in color. There was a slight growth of mold on the flank, on the tip of the loin, and on the exposed muscles at the butt of the round. The fat had become very dark in color. Although there were no apparent evidences of putrefaction, the quarter of beef was considered not to be in good marketable condition on account of the badly dried out condition of the meat.

The beef showed a shrinkage of 10 per cent during storage.

### QUALITY OF MEAT.

*Quarter of beef stored 68 hours.*—This quarter of beef was of only fair quality, being rather rough in form and very unevenly covered with fat. There was a heavy covering of fat on the top of the loin, while the round was poorly covered. The organoleptic properties

of the broiled test steak were described by the respective judges as follows:

Mr. A.—The tenderloin is fairly tender, the loin portion rather tough, and the flank end very tough. All portions of the steak have a good flavor.

Mr. B.—As a whole the steak has a good flavor and is fairly tender. The different portions follow the usual order as regards tenderness.

Mr. C.—The tenderloin and loin portions of the steak are comparatively tender, while the flank end is rather tough. The steak is juicy and has a good flavor.

*Quarter of beef stored 179 days, 20 hours.*—When the quarter of beef was cut up for analysis, the cut surface at the butt of the round had a normal red color. Where the surface of the meat was covered with fat, the red color extended to the fat; but where the muscles were exposed to the air, there was a dark-brown zone extending inward to a depth of about a quarter of an inch from the surface. The odor from the cut surface was a trifle "old" and somewhat acrid, but there was no odor of putrefaction. When the loin was cut up, the freshly cut surfaces had about the same appearance and odor as had the cut surface of the round. The kidney and external fat had a strong and rather rancid odor. The opinions of the judges as to the organoleptic properties of the broiled test steak were as follows:

Mr. A.—The loin portion is rather dry and has an "old" and rather unpleasant flavor. The flank portion is tougher than the loin and has an "old" flavor.

Mr. C.—On the whole the steak is comparatively dry and tough. The flavor is "old" and a trifle unpleasant. The quality of this steak is not nearly so good as that of steaks previously tested which had been cut from quarters of beef that had been held in cold storage for a few weeks. This steak may be classed as edible, but not palatable. No ill effects were suffered from eating the meat.

### CHEMICAL EXAMINATION OF CARCASS NO. 7.

Tables 54 to 60, inclusive, show the changes which took place in the composition of carcass No. 7 during 177 days in cold storage.

Table 54 shows the composition of the meat expressed in terms of percentages of the original material.

TABLE 54.—*Composition expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | | Moisture. | Fat. | Ash. | Total nitrogen. | Ammoniacal nitrogen. | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D. | H. | | | | | | Total. | Soluble. | Insoluble. |
| 88 | Round: Left hind quarter... | 2 | 20 | 73.59 | 3.73 | 1.07 | 3.42 | 0.0093 | 0.201 | 0.157 | 0.044 |
| 114 | Round: Right hind quarter.. | 179 | 20 | 70.91 | 4.66 | 1.13 | 3.49 | .0196 | .203 | .163 | .040 |
| 89 | Rump: Left hind quarter... | 2 | 20 | 71.61 | 6.32 | 1.01 | 3.26 | .0091 | .194 | .145 | .049 |
| 115 | Rump: Right hind quarter.. | 179 | 20 | 70.36 | 5.77 | 1.08 | 3.49 | .0205 | .190 | .154 | .036 |
| 90 | Loin: Left hind quarter..... | 2 | 20 | 69.06 | 9.01 | .98 | 3.23 | .0079 | .183 | .144 | .039 |
| 116 | Loin: Right hind quarter... | 179 | 20 | 69.80 | 6.19 | 1.09 | 3.35 | .0187 | .185 | .144 | .041 |

TABLE 56.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of fresh material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | D. H. | | | | | | | | | | | | |
| 88 | Round: Left hind quarter | 2 20 | 6.80 | 0.94 | 5.86 | 0.72 | 0.943 | 0.520 | 0.423 | 0.038 | 0.0842 | 0.157 | 0.110 | 0.047 |
| 114 | Round: Right hind quarter | 179 20 | 8.22 | 1.05 | 7.17 | .80 | 1.13 | .475 | .655 | .068 | .2253 | .163 | .153 | .010 |
| 89 | Rump: Left hind quarter | 2 20 | 7.04 | 1.10 | 5.94 | .69 | .938 | .512 | .426 | .037 | .0825 | .145 | .102 | .043 |
| 115 | Rump: Right hind quarter | 179 20 | 8.39 | .95 | 7.44 | .76 | 1.14 | .506 | .634 | .054 | .2570 | .154 | .141 | .013 |
| 90 | Loin: Left hind quarter | 2 20 | 6.90 | 1.04 | 5.87 | .69 | .998 | .577 | .421 | .035 | .0798 | .144 | .095 | .049 |
| 116 | Loin: Right hind quarter | 179 20 | 7.68 | .98 | 6.70 | .70 | 1.05 | .445 | .605 | .066 | .2213 | .144 | .137 | .007 |

TABLE 57.—*Composition of 0.9 per cent sodium chlorid extract of meat expressed in terms of percentages of moisture-free and fat-free material.*

| Serial No. | Description of sample. | Storage period. | Total solids. | Ash. | Organic extractives. | Acid as lactic. | Nitrogen. | | | | | Phosphorus. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Total soluble. | Soluble inorganic. | Soluble organic. |
| | | D. H. | | | | | | | | | | | | |
| 88 | Round: Left hind quarter | 2 20 | 30.00 | 4.13 | 25.87 | 3.18 | 4.16 | 2.29 | 1.87 | 0.168 | 0.3715 | 0.693 | 0.485 | 0.208 |
| 114 | Round: Right hind quarter | 179 20 | 33.64 | 4.30 | 29.34 | 3.27 | 4.62 | 1.94 | 2.68 | .278 | .9220 | .665 | .626 | .039 |
| | Change | 177 | +3.64 | +.17 | +3.47 | +.09 | +.46 | −.35 | +.81 | +.110 | +.5505 | −.028 | +.141 | −.169 |
| 89 | Rump: Left hind quarter | 2 20 | 31.90 | 4.99 | 26.91 | 3.12 | 4.25 | 2.32 | 1.93 | .168 | .3738 | .656 | .461 | .195 |
| 115 | Rump: Right hind quarter | 179 20 | 35.14 | 3.98 | 31.16 | 3.18 | 4.77 | 2.12 | 2.65 | .226 | 1.0764 | .644 | .591 | .053 |
| | Change | 177 | +3.24 | −1.01 | +4.25 | +.06 | +.52 | −.20 | +.72 | +.058 | +.7026 | −.012 | +.130 | −.142 |
| 90 | Loin: Left hind quarter | 2 20 | 31.45 | 4.72 | 26.73 | 2.14 | 4.55 | 2.63 | 1.92 | .159 | .3637 | .658 | .434 | .224 |
| 116 | Loin: Right hind quarter | 179 20 | 31.99 | 4.08 | 27.91 | 2.92 | 4.37 | 1.85 | 2.52 | .275 | .9221 | .599 | .570 | .029 |
| | Change | 177 | +.54 | −.64 | +1.18 | −.22 | −.18 | −.78 | +.60 | +.116 | +.5584 | −.059 | +.136 | −.195 |

TABLE 59.—*Distribution of nitrogen and phosphorus on basis of 100 parts of the respective constituents at beginning of storage period.*

| Serial No. | Description of sample. | Storage period. | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* *H.* | | | | | | | | | | | | |
| 88 | Round: Left hind quarter | 2 20 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 114 | Round: Right hind quarter | 179 20 | 94.77 | 111.16 | 84.88 | 143.34 | 165.64 | 248.18 | 196.34 | 93.64 | 85.07 | 96.06 | 129.06 | 19.10 |
| 89 | Rump: Left hind quarter | 2 20 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 115 | Rump: Right hind quarter | 179 20 | 99.10 | 112.34 | 91.34 | 137.57 | 134.61 | 287.96 | 208.52 | 90.41 | 67.29 | 98.26 | 128.35 | 27.18 |
| 90 | Loin: Left hind quarter | 2 20 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 116 | Loin: Right hind quarter | 179 20 | 94.93 | 96.13 | 70.49 | 131.27 | 172.92 | 253.53 | 216.07 | 92.08 | 95.77 | 91.08 | 131.35 | 12.96 |

TABLE 60.—*Distribution of nitrogen and phosphorus expressed as percentages of total nitrogen and total phosphorus.*

| Serial No. | Description of sample. | Storage period. | Nitrogen. | | | | | | | Phosphorus. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Soluble. | Coagulable. | Non-coagulable. | Proteose. | Amino. | Ammoniacal. | Total. | Insoluble. | Soluble. | Soluble inorganic. | Soluble organic. |
| | | *D.* *H.* | | | | | | | | | | | | |
| 88 | Round: Left hind quarter | 2 20 | 100.00 | 27.60 | 15.20 | 12.40 | 1.12 | 2.47 | 0.27 | 100.00 | 22.02 | 77.98 | 54.58 | 23.40 |
| 114 | Round: Right hind quarter | 179 20 | 100.00 | 32.38 | 13.61 | 18.77 | 1.95 | 6.46 | .56 | 100.00 | 20.02 | 79.98 | 75.21 | 4.77 |
| | Change | 177 | 0.00 | +17.29 | −10.43 | +51.24 | +74.78 | +161.87 | +107.34 | 0.00 | − 9.08 | + 2.57 | +37.80 | −79.62 |
| 89 | Rump: Left hind quarter | 2 20 | 100.00 | 28.81 | 15.73 | 13.08 | 1.14 | 2.53 | .28 | 100.00 | 25.35 | 74.65 | 52.46 | 22.19 |
| 115 | Rump: Right hind quarter | 179 20 | 100.00 | 32.66 | 14.50 | 18.16 | 1.55 | 7.36 | .59 | 100.00 | 18.87 | 81.13 | 74.46 | 6.67 |
| | Change | 177 | 0.00 | +13.36 | − 7.82 | +38.83 | +35.84 | +190.58 | +110.77 | 0.00 | −25.56 | + 8.68 | +41.94 | −69.94 |
| 90 | Loin: Left hind quarter | 2 20 | 100.00 | 30.95 | 17.89 | 13.06 | 1.08 | 2.47 | .25 | 100.00 | 21.25 | 78.75 | 51.97 | 26.78 |
| 116 | Loin: Right hind quarter | 179 20 | 100.00 | 31.34 | 13.28 | 18.06 | 1.97 | 6.61 | .56 | 100.00 | 22.11 | 77.89 | 74.12 | 3.77 |
| | Change | 177 | 0.00 | + 1.26 | −25.75 | +38.27 | +82.15 | +167.06 | +127.76 | 0.00 | + 4.05 | − 1.09 | +42.62 | −85.92 |

less than that obtained in Experiment No. 5. The changes, on the whole, are rather small in comparison with the length of the storage period; though it should be noted, in this connection, that the amount of preformed soluble inorganic phosphorus in the fresh meat was rather large.

The changes that took place in the ratios of soluble organic phosphorus to total phosphorus have rather less significance than the corresponding changes in the inorganic phosphorus ratios.

## SUMMARY OF CHEMICAL AND PHYSICAL STUDIES.

The general purpose of the cold-storage experiments, the results of which have been reported in some detail, was to determine the cause, nature, and extent of the changes that take place in fresh beef during cold storage, with particular reference to the effect of such changes upon the wholesomeness and nutritive value of the product.

As regards the conditions of storage, the experiments may be divided into two groups, the first of which would include those experiments carried out in the bureau's cold-storage room, and the second of which would consist of the single experiment conducted in the packing-house cooler. The first group includes Experiments Nos. 1, 2, 3, 4, 5, and 7, while the second group consists of Experiment No. 6. The two series of experiments are of value in showing the effect of different conditions of storage upon the nature and extent of the changes which take place in beef during storage and upon the length of the storage period.

In the experiments of the first group the conditions of storage were fairly uniform, the temperatures varying between 32° and 36° F., and the humidity between 70 and 80 per cent of saturation. The principal variable element in these experiments was the length of the storage period, so that, in large part at least, the difference in the extent of the changes which took place in the beef in the several experiments may be considered as due to this factor.

In the case of Experiment No. 6, which was carried out in the packing-house cooler, the conditions of storage were also fairly uniform throughout the experiment. The temperature varied between 28° and 32° F., but remained, for the most part, at 32° F., and the humidity ranged from 92 to 95 per cent of saturation.

Certain differences were observed in the initial composition of the beef used in the several experiments, and these had to be taken into consideration in order properly to interpret the changes that took place in the meat during storage.

## PHYSICAL CHARACTERISTICS OF THE BEEF.

In the series of experiments carried on in the bureau's cold-storage room, the principal effects of storage upon the physical characteristics of the beef were shrinkage in weight and a hardening and darkening

The quarter of beef that had been held in storage in the packing-house cooler for a period of 54 days possessed organoleptic properties that were similar to the beef that had been stored in the bureau's cold-storage room for approximately the same periods of time. The growth of mold upon this quarter of beef was a surface condition, and while it was indicative of conditions favorable to the rapid development of bacteria and the consequent deterioration of the meat, no such change had yet taken place.

Although in a few instances exposed portions of the stored quarters of beef showed signs of deterioration, yet in all cases, as judged by the organoleptic tests ordinarily applied, the edible portions of these quarters would have been classed as wholesome. The authors ate liberally of the test steak cut from each quarter of beef, both fresh and stored, and in no case did they suffer any ill effects from so doing. In this connection, however, it should be noted that the authors were healthy and well-nourished individuals.

### CHEMICAL CHANGES IN THE BEEF.

Briefly summarized, the changes which took place in the chemical composition of the beef during storage consisted of a transformation of the more complex constituents of the meat into simpler compounds, with the consequent accumulation of certain of the end products of those changes. In general the extent of the changes increased with the period of storage. The changes were very similar in nature to, but less in extent than, those that took place in lean beef during aseptic autolysis, as reported in a previous section of this paper.

Since the results of the bacteriological studies of the beef have shown that there was no appreciable penetration of bacteria into the meat during storage it may be concluded that the changes which took place in the beef were due, in large part at least, to the action of enzyms. Exception must be made to the kidney and external fatty tissues, which were exposed to the action of bacteria.

The changes which took place in the individual constituents of the meat during storage and the significance of those changes as affecting the wholesomeness and nutritive value of the meat are discussed in the following paragraphs.

*Moisture, fat-free basis.*—Expecting in the case of the quarter of beef stored for 14 days the moisture content of the meat decreased during storage. In general the loss of moisture became greater as the period of storage was lengthened, but the loss occurred less rapidly in the meat stored in the packing-house cooler, with its high humidity, than in the beef stored in the bureau's cold-storage room at a lower humidity. These facts are in keeping with the observations made concerning the shrinkage in weight of the cold-storage beef.

*Ash.*—The slight irregular changes noted in this constituent are without significance.

*Total nitrogen.*—With the exception of the quarter of beef that had been held in storage for 14 days, where there was an apparent increase in the nitrogen content of the meat, each quarter of beef showed a slight apparent decrease in nitrogen content during storage. The increase in nitrogen in the one instance must be regarded as due to some unknown analytical error; but the fact that the nitrogen content of all the other quarters of beef that had been stored for longer periods of time decreased makes it appear that there was a slight actual loss of nitrogen from the meat during storage. However, the decreases were not distinct enough to make the results convincing.

*Total soluble solids.*—The changes that took place in this constituent during the storage of the beef did not bear a direct relation either to the length of the storage period or to the conditions of storage. The quarters stored for 14, 28, and 63 days showed considerable decreases in total soluble solids; that stored for 42 days showed practically no change; while those stored for 54, 74, and 177 days showed distinct increases. The decreases in the amount of total soluble solids that occurred during the storage periods are contrary to the commonly accepted idea that there is necessarily an increase in this constituent of meat during storage. It appears that there was first a decrease in total soluble solids in the early part of the storage period, and later an increase in this constituent as the storage period was lengthened. The probable explanation of these peculiar changes will be discussed in connection with total soluble nitrogen.

*Ash of extract.*—On account of an unavoidable analytical error encountered in the determination of this constituent, due to the necessity of correcting for a relatively large quantity of sodium chlorid in the presence of a small amount of ash, the data for this constituent are not considered to have any special significance.

*Organic extractives.*—The changes in this constituent were of the same general character as those which took place in the total solids.

*Total soluble nitrogen.*—The changes that took place in this constituent did not proceed in regular order. Beef stored for 14, 28, and 63 days showed slight decreases in total soluble nitrogen, while that stored for 42, 54, 74, and 177 days exhibited slight to appreciable gains in that constituent. On the whole the changes in total soluble nitrogen during storage were not large.

The interpretation of these changes, however, is of considerable significance. The probable explanation of the initial decrease in total soluble nitrogen and of the subsequent increase in that constituent is, in general, the same as that which has already been suggested to account for the similar changes observed in the autolysis experiment reported in a previous part of this paper. That explanation need not be repeated here.

The increases observed in the total soluble nitrogen content of meat stored for longer periods must be regarded as being due, in large part

at least, to enzym action. In the light of present information the enzym protease may be considered as the active agent.

*Coagulable nitrogen.*—The changes that took place in this constituent during storage consisted of fairly marked decreases, which in general became larger as the storage period was lengthened. However, because of the irregular changes that took place in total soluble nitrogen, which in turn affected the amounts of coagulable nitrogen present in the meat at a given time, the full extent of the transformation of coagulable nitrogen into noncoagulable forms is not shown by the decreases in coagulable nitrogen, but is shown rather by the increases in noncoagulable nitrogen.

*Noncoagulable nitrogen.*—This constituent increased continuously throughout the cold-storage periods employed in these experiments. The average increase in the noncoagulable nitrogen in the beef stored for 14 days was 1.36 per cent, while the increase in the beef stored for 177 days was 37.39 per cent of the noncoagulable nitrogen originally present. In large part at least, the changes of coagulable protein into noncoagulable forms may be regarded as being due to the action of the enzym protease.

*Proteose nitrogen.*—While the relative increase in this constituent during storage was large in each experiment, there was no direct relation between the length of the storage period and the increase in proteose nitrogen. The average increase in this constituent during 14 days of storage amounted to 34.04 per cent and the increase during 54 days of storage amounted to 268.91 per cent of the amount initially present, while the increase observed in case of the quarter stored for 177 days amounted to but 57.72 per cent of the proteose nitrogen initially present. The proteoses are, of course, an intermediate product in the autolysis of muscle proteins, and no marked accumulation of this product during cold storage was to have been expected. While in some cases the increases in the proteose content of the cold-storage meat were relatively large, yet in no case did the proteose nitrogen constitute any considerable proportion of the total nitrogen of the meat, the maximum average percentage being 1.97 in the case of carcass No. 6, which had been stored for a period of 54 days.

*Amino nitrogen.*—Without exception, each quarter of beef contained more amino nitrogen at the end of its storage period than did the corresponding fresh quarter, and likewise, without exception, the longer a quarter was held in storage at a given temperature the greater was the relative increase in this constituent. In the quarter that was stored in the packing-house cooler for 54 days, however, the amino nitrogen did not increase by as great an amount as did that in the quarter held in storage in the bureau's cold-storage room for 42 days. This was probably due to the lower storage temperature in the first instance.

On account of the many factors that seem to influence the formation of ammoniacal nitrogen and because of the small quantities of ammoniacal nitrogen found in the beef, even after long periods of storage, the changes in this constituent have not constituted a good index of the extent of autolysis in the cold-stored beef; nor can they be regarded as being of any practical significance. The production of ammonia is probably largely due to the combined action of several proteolytic enzyms.

*Acidity.*—The beef stored for 14, 28, and 177 days showed slight apparent decreases in acidity, while that stored for 42, 63, and 74 days exhibited from slight to appreciable gains in that constituent. The presence of acid-forming enzyms in muscular tissue is well known, and the increases that took place in the acidity of the meats were undoubtedly due, in large part at least, to enzym action.

*Total phosphorus.*—With the exception of the quarter of beef stored for 14 days, each cold-stored quarter contained less total phosphorus than the corresponding fresh quarter. This seeming loss of phosphorus was accompanied in every case but one by a corresponding loss in total nitrogen. Similar variations in total phosphorus and total nitrogen were observed during the autolysis experiment. Of themselves these data would go to show that phosphorus actually was lost from the meat during storage; yet, in view of the improbability of such an occurrence and the smallness of the apparent losses, the evidence would scarcely justify such a conclusion.

*Insoluble phosphorus* was determined by difference, and what is stated in the following paragraph applies inversely to this constituent.

*Total soluble phosphorus.*—The changes that occurred in total soluble phosphorus during the cold storage of the beef were of a very irregular nature. The changes were sometimes large and sometimes small, sometimes positive and sometimes negative, but in no case did they seem to bear any relation to any known factor. Even in Experiment No. 7, where the storage period was 177 days, two decreases and one increase in this constituent were observed. It can only be inferred that the solubility of some portion of the organic phosphorus was influenced by some obscure factor that was not properly controlled in these experiments, and which escaped detection in the autolysis experiment in consequence of the extensive cleavage of insoluble phosphorus. Obviously, therefore, in the present case no particular significance can be attached to these irregular changes.

*Soluble organic phosphorus.*—The changes that have occurred in the soluble organic phosphorus of the beef during the storage periods of these experiments appear to have been influenced not only by the length of the storage period and by the temperature of storage, but also by the relative amounts of preformed soluble organic and inorganic phosphorus contained in the fresh material. In order that these relations may be studied, therefore, the experiments must be classified, not only with reference to the time and the temperature of storage, but also with regard to the initial distribution of soluble organic and inorganic phosphorus. In reference to the latter factor, Experiments Nos. 2 and 4 should be placed in one group and the other experiments in a second group, since the material used in Experiments Nos. 2 and 4 each contained a greater proportion of total phosphorus in the soluble inorganic form and a smaller proportion

explained by the comparatively large increases in the amount of free fatty acids present in those samples.

*Free fatty acids.*—There was a marked and continuous increase in the free fatty acid content of the external and kidney fats during the course of the storage experiments and a corresponding deterioration in the quality of those fats. The average actual increase in the acidity of the two fats ranged from 0.46 per cent in the case of the beef stored 14 days to 9.76 per cent in the case of that stored 177 days. The changes in the acidity of the intermuscular fat were comparatively small, varying from an increase of 0.17 per cent in the case of the beef stored for 14 days to an increase of 1.42 per cent in the case of that stored for 74 days. The reason for the slight increase in the acidity of the intermuscular fat as compared with the large increases in the acidity of the kidney and external fats is clearly apparent. The intermuscular fat was protected from bacteriological invasion by its covering of muscular and external fatty tissues, while the kidney and external fats were exposed to the invasion of molds and bacteria. The changes that took place in the intermuscular fat were due, in very large part at least, to the action of the enzym lipase, while the changes that took place in the kidney and external fats were due principally to bacterial action.

## EFFECTS OF COLD STORAGE UPON THE NUTRITIVE VALUE OF THE BEEF.

Several factors must be taken into consideration in order properly to interpret the results of these experiments in terms of their effect upon the nutritive value of the meat. The more important factors are as follows: (1) Changes in the moisture content of the meat; (2) changes in the proportions of nonedible and edible meat in the quarters of beef; (3) changes in the composition of the meat.

The analytical data obtained in these experiments show that, with the exception of the quarter of beef that had been stored for 14 days, each of the quarters lost moisture during storage, and that in general the decrease in the moisture content of the meat was greater the longer the storage period. This loss of moisture is in effect a process of concentration, causing an actual increase in the amount of food constituents present in a given weight of stored meat, as compared with that present in a like weight of fresh meat. Thus, by referring to Tables 19, 26, 33, 40, 47, and 54 it may be noted that the average percentages of total nitrogen, fat, and ash increased during the storage period of each experiment, and that in general the increase was greater the longer the period of storage. These data show the composition of the lean meat and are a fair indication of the extent to which the nutritive value per given weight of meat was increased through loss of moisture.

The increase in nutritive value, however, is only apparent, not real; for while the loss of moisture effects an increase in the nutritive value of the meat per unit weight, it also diminishes the weight of the carcass; so that at best the carcass contains no more nutritive material after storage than before. Indeed, the available food material in the carcass tends to become less; for, in consequence of the drying out and deterioration in quality of the exposed muscular and fatty tissues, there is greater wastage in the preparation of the retail

on account of the deficiency of our knowledge regarding the nutritive values of the various cleavage products, it is by no means impossible that the nutritive value of beef may be decreased by unduly long periods of storage.

## FACTORS AFFECTING THE TIME THAT FRESH BEEF CAN BE STORED AT TEMPERATURES ABOVE FREEZING.

One of the objects in conducting the series of experiments reported in this paper was to determine the length of time that fresh beef could be held in cold storage at temperatures above freezing and remain in wholesome condition. The results of these experiments and of observations upon the commercial handling of fresh beef in cold storage have shown that the possible length of the storage period is affected by a number of factors. On account of the importance that has been attached to the time element in the cold storage of fresh beef, and in the storage of other fresh meats as well, it has seemed desirable to present a brief discussion of this phase of the subject.

The principal factors which affect the length of time that fresh beef can be held in cold storage at temperatures above freezing are as follows: (1) The character of the beef; (2) the temperature of storage; (3) the humidity of the cold-storage room.

*Character of beef.*—The condition of beef, as regards its degree of fatness or finish, is an important factor in determining the length of time that the beef will keep in cold storage. Thin, soft carcasses of old cows or grass-fed cattle are apt to undergo comparatively rapid deterioration in cold storage. The large exposed surface of muscular tissue and the soft character of the meat offer favorable conditions for the development of molds and bacteria. It is generally recognized by packing-house men that beef of this character must be handled with dispatch. On the other hand, highly finished carcasses from prime, grain-fed cattle will keep in cold storage for a much longer time. The flesh of such carcasses, which is firm in character, is usually covered in large part with a surface deposit of fatty tissue, which becomes firm on cooling and through loss of moisture, and thus aids in protecting the muscular tissue against bacterial invasion.

*Temperature of storage.*—In commercial practice chilled beef is ordinarily held in cold storage at a temperature between 34° and 36° F., although occasionally temperatures as low as 30° F. or as high as 40° F. may be employed. A temperature of 40° F. is regarded as about the upper limit of safety in the handling of fresh beef in cold storage, while it will freeze at a temperature slightly under 31° F. Other conditions being the same it is clearly apparent that chilled beef will keep longest at 31° F.

*Humidity of cold-storage rooms.*—The importance of dry coolers for the proper handling of chilled beef is generally recognized. As a rule, however, no special means are used to regulate the humidity of beef or other fresh-meat coolers, the desired condition usually being obtained by the proper construction and management of the coolers. Various factors may affect the humidity of coolers, but they will not be discussed.

There seems to be practically no information available regarding the humidity of packing-house coolers in this country. In order to secure accurate information on this subject, humidity readings were

tures above freezing, it is clearly impracticable to attempt to insure the wholesomeness of the product merely by limiting the duration of storage. The wholesomeness of cold-stored beef must be judged by other considerations besides the length of time that the product has been held in cold storage.

## GENERAL SUMMARY.

The chemical changes that took place in the muscular tissue of beef held in cold storage at temperatures above freezing for periods ranging from 14 to 177 days consisted chiefly in increases in acidity; in proteose, noncoagulable, amino, and ammoniacal nitrogen; and in soluble inorganic phosphorus; while decreases occurred in coagulable nitrogen and in soluble organic phosphorus. On the whole these changes were of a progressive nature. The chemical changes that took place in the fatty tissues of the beef consisted chiefly in marked increases in the acidity of the kidney and external fats.

On the whole the chemical changes that took place in the muscular tissue of the beef during storage were similar in nature to but less in extent than those that were caused by enzymatic action when lean beef was autolyzed under aseptic conditions for periods ranging from 7 to 100 days.

The chemical changes that took place in the muscular tissue of the beef during storage were without appreciable effect either upon the nutritive value or the wholesomeness of the edible portions of the product; but the changes that took place in the kidney fat and external fatty tissue after the longer periods of storage rendered them unsuitable for human consumption.

The bacteria and molds which grew on the surface of the cold-stored meats did not penetrate the muscular tissue to any great depth. The increased tenderness noticed in the cold-stored meats could not be attributed to bacterial action; and no noticeable change in the histological structure of the muscle fibers was noticed after 11 weeks of storage.

The chemical changes which took place in the muscular tissues of the beef during storage may be regarded as largely due to enzym action.

The principal effect of storage upon the organoleptic properties of the beef was a marked increase in tenderness of the meat. This change did not appear to progress appreciably after the beef had been held in storage for from two to four weeks. While the flavor also changed, individuals would probably not agree as to whether the change was in the nature of an improvement or a deterioration.

Beef was held in cold storage at temperatures above freezing in an experimental cooler for as long as 177 days, whereas it was possible to hold beef in storage in a cooler in a modern packing house for only 55 days. The shorter storage period in the second instance was due to the much higher humidity of the packing-house cooler as compared with the experimental cooler.

The length of time that fresh beef can be held in cold storage at temperatures above freezing and remain in wholesome condition is dependent upon a number of factors, among which the temperature and humidity of the storage room and the character of the beef are of the most importance.